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TRANSACTIONS

of the

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Vol. III Cleveland, February, 1923 No. 5

STEEL OUTLOOK GOOD

DURING the past year, the iron and steel production of the country, which is the unfailing barometer of general industrial activity, has displayed an impressive exhibition of recovery and expansion. This improvement which has taken place since the middle of 1921 has been almost continuous, and its extent as indicated by the fact that the tonnage of pig iron during the last month of 1922, was more than two and one half times as great as it was in July, 1921.

At the present time there is every indication that this prevailing activity of the iron and steel industry will continue during the coming year. The general recovery of business which is now in progress was in a large measure started and kept up by the building construction boom during the past year and one half. Also, the renewed purchasing activity of the railroads and the unexpected extensive activity of the automobile industry has aided this progress to no small degree.

Nearly 50 per cent of the iron and steel of the country is consumed by the building construction business, the automotive industry and the railroads, and if the tonnage of iron and steel used in the oil, gas and water installations be added to this list, we would find that these industries consume more than 60 per cent of the total tonnage of finished steel produced in the United States. Statistics show that for every 100 tons of steel which is produced, about 25 per cent is used by the railroads, about 15 per cent for oil, gas and water pipes and tanks, about 13 per cent for building construction, and 9 per cent for the automotive industry.

These facts warrant the prediction that the iron and steel industry will undoubtedly enjoy an active and prosperous year. It is patent that there is still a shortage of building construction, and of railroad equipment and moreover it seems certain that during the next year there will be a very great volume of automobiles produced and sold.

The iron and steel industry at the present time is illustrating one of the economic principles of periods of business recovery, which has frequently been observed in previous years. This results from the condition that when business begins to expand after a period of depression, those firms which first return to a profit making basis are those manufacturing products which are sold directly to the consumer. As this rule operates, firms producing and selling direct, usually draw upon their storage surpluses and manufacture their products from these reserves. It is not until some time later that it is necessary for them to buy new

raw materials to carry on their production. This has been the condition for the past year and one half with the result that the present year promises to be a year of very much increased activity for the steel business in replenishing the raw material supply for further manufacture into finished products.

COMMERCIAL TRAINING OF ENGINEERS ESSENTIAL

THAT engineering college graduates are handicapped without a supplementary commercial training is the basis of research investigations recently completed by Dr. W. F. Rittman and W. F. Reilly, of Carnegie Institute of Technology, Pittsburgh. In the *Carnegie Technical Journal*, a quarterly publication of the alumni and students of Carnegie Tech, Messrs. Rittman and Reilly present substantial proof of the need of commercial training in technological college courses.

With the co-operation of the alumni office, a study of the present occupations of Carnegie Tech graduates was made. Of the graduates from 1908 to 1921, the investigations showed that approximately 67 per cent of the total engineering graduates are now engaged in commercial or managerial work. This majority becomes significant in consideration of the fact that "engineering" graduates include a wide range of highly technical fields such as mechanical, electrical, civil, chemical, metallurgical, mining, sanitary, and science.

An interesting tabulation in the report shows the following percentages of engineering graduates in all departments who are now in commercial or managerial capacities: mechanical engineering, 65 per cent; electrical engineering, 60 per cent; civil engineering, 73 per cent; chemical engineering, 59 per cent; commercial engineering, 91 per cent; metallurgical and mining engineering, 67 per cent; sanitary engineering, 60 per cent; science, 77 per cent.

One of the two most important generalizations cited by the authors in their report is that "the great majority of graduates use their technical education as a means of getting into commercial or managerial work. It is believed that a similar study of the activities of the graduates of other technical institutions corresponding to Carnegie Institute of Technology would show this same order of classification, which seems to be natural and in conformity with the trend of the times."

GOING UP

THERE are many important factors necessary to success. These necessary factors will vary according to the line of work one is in, but there are certain fundamental principles of success that are common to all lines of industry.

Probably first and foremost in the list one would place strength of character. Character is a tangible asset and while it is possessed by nearly everyone to a certain degree it may be in either a strong, medium or weak condition. Character must have great tensile strength because it will be subject on many occasions to serious strains, and

consequently must be able to withstand the depreciable effects of fatigue.

Next on the list one would place genuine fondness of work and a particular fondness for the work one is in. One too frequently is accustomed to feel the truth of the old saying "everything is beautiful where I am not", thinking that other lines of work have more attractiveness than their own, but going up to the top is always attained by those individuals who are in a work to which they are best adapted and to which they are of course able to give their best endeavors.

Success entails the willingness to finish the work of others as well as a bad memory for quitting time. One should always be conscious and have a due sense of appreciation of the other fellow's efforts and a constant striving to increase your own efficiency as well as outdistance the accomplishments of others in the organization.

A certain steel given the proper heat treatment will possess real ability to perform the work for which it is intended and so it is with the individual who wishes to ascend to the top of the ladder, he must have real ability for the work in hand as well as good judgment and common sense. Good judgment and common sense as well as real ability, is a respectable order but they are possessed by many members of our society who have failed to have sufficient confidence in themselves to let their light shine outside of the cover of the bushel basket.

Intimately joined with the above formula for reaching the top, is that the individual should have a never failing ambition. Ambition after all is one of the prime requisites for rising above the ordinary individual with whom we all start and one's rise will be in direct proportion as one cultivates and continues ambition—the stepping stone to success.

STEPS FORWARD

TWO valuable contributions in the form of symposia are added to to our fund of information. These symposia were held at the 1922 annual convention of the society in Detroit. Under the chairmanship of one profoundly interested in the hardness testing of metals, the hardness testing symposium has made commendable strides toward the solution of the problem of, first, determining what property of a metal the term hardness specifies and second, how this property can be accurately measured, both scientifically and practically.

Of the various methods of measuring hardness, no one of them seems to be adequate in determining the hardness of the many types of materials found in commercial work. The committee in charge of this work is carrying forward this capable undertaking and we may well expect to hear favorable progress reports from time to time.

The second symposium had to do with the proper and adequate training of students in our many educational institutions. Many interesting points relative to revamping present curriculums in our technical schools were brought out. The gist of this entire symposium was not how to teach but what to teach. Many valuable contributions to this session were made and it is more than likely that this work will assist numerous educators in rearranging their curriculums to better meet the demands of the engineering profession in the future.

SYMPOSIUM ON HARDNESS TESTING HELD AT THE FOURTH ANNUAL CONVENTION OF THE SOCIETY, DETROIT, OCTOBER, 1922

THIS meeting under the chairmanship of Major A. E. Bellis, was called to order at 11 a. m. Friday, Oct. 6, 1922. In opening Major Bellis presented briefly the objects of the symposium and commented upon the results of recent investigations along this line. Following these introductory remarks the first speaker presented his paper as follows:

SIGNIFICANCE OF HARDNESS TESTS

By H. P. Hollnagel, Ph. D.

Introduction

THE term *hardness* is used to mean so many different things, and has received so much attention in recent years, that it seems desirable to gather some of the facts in a more concrete form.

The present paper, therefore, calls attention to a diversity of viewpoints and to those physical properties which are always intermingled with hardness discussions.

Definitions of Hardness and Allied Properties

A physicist tests a piece of steel for its hardness. In so doing, he skilfully places and adjusts a microscope so that he may properly observe the specimens, and then causes a very fine scratch to be made with the proper implement under slight pressure (using the crystallographer's hardness scale wherewith to judge it). This under reproducible conditions. He then carefully examines the width, depth and general physical character of the scratch as the microscope is moved from crystal to crystal, studies the wonderful realm thus opened to him, and from this survey determines the hardness.

The engineer scratches the same specimen with a file or some tool, whose angle is definitely known, and under a pressure determinate or otherwise, applied in a similar manner. He arrives at a degree of hardness established by an elimination test as determined from a series of such tools drawn to certain degrees of hardness. Definite and reproducible conditions are established in making his determination and he is satisfied with the result of this interesting test. He compares the value thus obtained with that of the physicist and finds it very different. Why? Because one deals with the exceedingly minute, while the other deals with the average; one is a microscopist, the other a macroscopist. How can they hope to agree? Impossible without some correlation!

Concept

The concept of hardness originates from a sense of resistance offered by material to the action of an approximately static force. As to its specific

A paper presented before the Detroit convention Symposium on Hardness Testing, October 6, 1922. The author, Dr. H. P. Hollnagel, is associated with the department of physics of the Thomson Research Laboratory of the General Electric Co., West Lynn, Mass.

The Symposium on Hardness Testing was under the direction of the Hardness Testing Committee of the National Research Council of which committee Major A. E. Bellis, is chairman.

character, there is diversity of opinion; the engineer believes it fundamentally important, while the physicist does not recognize it as one of the more essential properties of matter.

There seem to be two general classes of hardness—superficial hardness, otherwise referred to as resistance to abrasion, and penetration hardness, otherwise referred to as deformation hardness. Both of these are spoken of as resistance to penetration or deformation of shape. In practice, one seldom occurs without the other; whether the cutting of a metal, or its wear and tear upon another under pressure is considered.

A so-called academic definition of this engineering property should cover both classes and might be stated as follows: Hardness is the cohesive resistance of the molecular-aggregate structure of a material to any deformation of form. For the engineer, this is utterly worthless. He neither deals with limited structures uniformly loaded, nor with large molecular aggregates in which there are highly localized strains, but rather with the combination of the two. Seldom is the stress so distributed, that either of the two may be considered applicable to or independent of the other.

Moreover, mechanical limitations such as dimensions, manner of application of the stress, together with its magnitude and duration, are factors of a very indefinite character. The result of such indeterminateness is a multiplicity of definitions, depending largely upon the personal aims of particular individuals.

Among these definitions, may be mentioned hardness, as determined by scratch, wear, rebound, crushing, bending, penetration and deformation and impact.

Scratch Hardness

Perhaps the oldest of these is scratch hardness, which characterizes the property or quality whereby one material abrades another, the scratched material being the less hard. For the mineralogist the Moh scale, Diamond 10, Sapphire 9—Gypsum 2, Talc 1 is standard, the high numbers being harder than those beneath them. Referred to this basis, the engineer utilizes a file test, ascribing a hardness of 6, 5 or 7 to such materials as are scratched by a file of a certain type. Copper and ductile wrought iron are thus rated as 3 and 4.5 respectively.

Wear

Hardness is also defined as the resistance to wear as determined by the amount of material removed measured in thousandths of millimeters; the degree of hardness is thus fixed if worn off under fixed load in proportionate times. Very often this hardness has been confused with and interpreted as that of scratch, but as will be seen, this is not permissible.

Rebound

In the ball bearing industry, the height to which the specimens rebound, when dropped upon a fixed plate properly hardened, has been taken as a measure of hardness. This is not truly a hardness test, but rather an indication of the resilience of the material. It measures the energy stored in the compression wave of both the material being tested, and that upon which rebound takes place. If you like, it measures the coefficient of restitution of

this material with respect to the plate. This may in certain types of test cause the yield point to be exceeded, in which case true resilience is not obtained, but rather that of deformed material.

Crushing

Still another test makes use of the crushing of the specimens themselves. In this case, the fracture is examined microscopically and the hardness judged therefrom. Presumably, the degree of packing determines the hardness characteristics in this case.

Bending

For wires and small sectional specimens, the resistance offered to bending is very often taken as a measurement of hardness. In such cases, it is customary to determine the number of reversals, to which a given specimen may be subjected without rupture, by bending through definite angles. The lower the number, the harder the material.

Penetration

Resistance offered by material to penetration is more generally said to be the definition of hardness. It is preferable to use the term "penetration" rather than "deformation" as the latter should be reserved for another characteristic. In measurements of the type which require the surface to be penetrated, it is necessary that the proportionality limit of a portion of the material be exceeded as well as the yield point. Once the latter has taken place, further deformation of material meets with resistance which is more than proportionately greater. This resistance is what I have elected to call "deformation hardness." It is the resistance to deformation beyond the proportionality limit and yield point of the material, and is the type of hardness usually measured by any of the indentation devices.

Penetration, just through a surface, will determine superficial hardness; through a definite thickness of material thereby causing permanent set, a hardness dependent upon the heat treatment to that depth; to a depth greater than this, a value of greater magnitude depending entirely upon the depth of such indentation. In practice, these hardnesses are all dependent upon the deformed state; that is, the material ahead of a penetration device is packed more and more once the proportionality limit is exceeded and becomes harder to the point of rupture.

Impact

For the cases thus far discussed, the outstanding physical treatment common to all is deformation of form. To be sure, deformation is not accomplished in exactly the same manner, and in most cases, is attended by permanent set. There is the exception—the elastic resilience of balls, in which case permanent set rarely occurs. If the contrary is the case, the test no longer is a measure of resilience alone.

Almost any impact hardness test is either of the resilient or semiresilient type. In a hardness test in the ordinary sense of the term, a permanent deformation is produced. In such cases, hardness is at times defined as the energy expended per unit volume of the indentation caused by impact. This is an unfortunate concept, as resistance is force, and should not be misconstrued with energy which is its space inegral. As has been previously alluded to, impact is usually accompanied by a rebound which depends on the rate

at which the compression wave travels into the specimen and the impacting medium. If you choose, rebound is a function of the duration of impact.

Time

In general, no restrictions are placed on the time of application of the stresses. One might conclude from this that time was of no consequence in hardness testing. A simple consideration of the time required to accelerate masses to a given velocity, however, calls to mind the fact that it is very important even though such masses be of molecular magnitude. We are concerned usually with such as are caused to slip upon like molecular masses, and from this viewpoint a force constantly applied for a considerable time should ultimately penetrate farther into a material of given hardness, other things being equal, than one characterized by the same momentum, but acting for an indefinitely short interval. The latter force might well surpass by a very great margin, the proportionality limit and yield point, and the material not show signs of rupture. In a few words, it requires time for slippage to occur. (Brittle materials are referred to later.)

It is evident that there is insufficient agreement among various definitions and those factors which determine their validity, and that more definite specifications are required.

Let us examine some of the reasons for failure of a few of these definitions and tests.

Discussion of Tests

Scratch Test

Can a scratch give a true value of hardness? It is questionable, for it depends

1. Upon the operator's personal equation
2. Pressure at which the tool is applied
3. Type and character of tool
4. Angle at which tool is ground, and at which it is applied to the work
5. Speed of application
6. The uniformity and character of material

Furthermore, diamond cuts diamond, broken glass cuts glass, depending entirely upon a molecular rearrangement of amorphous material on fracture, and the chemical constitution of specimens. The grain structure of diamond, which makes possible the cutting of a stone by its chips, probably is a molecular rearrangement at slip planes whereby this region becomes much harder. That is, its physical properties are much changed in a manner somewhat similar to the case of the modified virgin material within the earth about a geologic fault after the same has occurred.

Effect of Speed

As all of the determining characteristics of a scratch excepting the fifth are fairly self evident, it may not be out of place to cite experimental evidence in substantiation of the effect of speed.

A wrought iron disc rotating at a linear speed of 30 feet per second may readily be cut by a steel tool; when rotating at 100 feet per second, it readily cuts steel tools, and when rotating at 300 feet per second, it readily cuts quartz, which has a hardness number of 7 based on the Moh scale. That is to say, it is as hard as a steel file. Speed therefore is a very important factor and should be given due consideration in cutting operations.

Resistance To Wear

May one conclude from a scratch test that resistance to wear of a piece of steel shafting is predetermined? This is questionable; after the first few 1000 revolutions of the shaft, its surface is no longer in the original state, it is polished, and, though not measurable by any of the present methods, is harder than before. A polished metallic surface is considered to be an amorphous state of metal. Under polishing conditions, the metal becomes plastic and solidifies at a rate permitting of the formation of no new crystalline masses, rather any fractured crystals which may occur act as nuclei about which the metal is packed more closely than before. This means finer grain structure.

Under conditions of wear, in a bearing, these circumstances are approached and the shafting hardens on the surface as the wear progresses. This is generally referred to as the packing of fine grains among the larger, and where the load is the greatest, the packing with its resulting hardness is a maximum.

Analysis of Scratch

In itself a scratch is not a proper indication of hardness. It may be considered a measure of a surface property—Scratchivity—which is related to the skin hardness of a material. Examined closer, how may one consider a scratch produced?

A sharp instrument under normally, or otherwise applied pressure bears on a surface; before a scratch is begun, an indentation is produced locally, either gradually or suddenly, so that as the tool advances, the material ahead of it is compressed; the proportionality limit and yield point are exceeded and rupture caused. An aggregate of grains topples out, others are packed into slip planes; the further application of continued stress on material already distorted causes more compression and incipient cracks, rupture and more loose grains, and so the scratch progresses. Unquestionably, such cracks may be observed in the material just ahead of the tool. While all of this occurs in a very short interval of time, it has the elements of every deformation and rupture process; there being, however, no material above the surface along which the tool is traveling. Slipping takes place more readily in a direction in the neighborhood of 45 degrees with the horizontal which causes a lower degree of hardness on the average than the hardening effect alluded to above, that is the hardening caused by deformation. Therefore, when compared with indentation hardness, it will of necessity be low.

Hardness By Penetration

In studying hardness as measured by penetration, one is confronted with the unfortunate features of all penetration hardness methods, when attempting to characterize the physical properties of a material like manganese steel. By their use, one is not able to differentiate between the characteristics of manganese steel in its virgin, rolled or worn state. In fact, this is the crux of the whole situation. A material under compression changes in hardness, becomes more resistant to penetration as it increases up to the point of rupture of grain structure. Certain bronzes and duralumin act in exactly the same manner as manganese steel, showing different hardnesses after being rolled, hammered or worked. Therefore, it would seem that hardness depends as much upon the degree to which material has previously been deformed, as it does upon the rate at which this deformation has been carried out; in either case, these factors vary considerably with the material.

Can a penetration test lead to a true hardness? It would appear likely

if deformation were carried out to the yield point so rapidly that the resistant force at this point would be a true measure of the cohesive resistance. But can one uniformly load or stress a portion of material at a point just below rupture? Can one measure the true deformation at this point, having accomplished it in a proper time? Neither of these questions can be answered in the affirmative. Considering the time involved to stress a body to its yield point, which may be impracticable, the answer is not simple.

Rebound and Impact

Rebound or impact may only determine the degree of hardness when the proof resilience has actually been approached. This is a decided function of the time of application of the impulse stress during which the ultimate limit may well be exceeded in value and still no permanent deformation result (this time must be sufficiently small). Moreover, the same and different materials have different proof resiliences, depending largely upon what their previous history may have been. Therefore, different impulse times will result and only such determinations can have significance when materials have uniform distribution of mass and equal times of impulse.

Crushing and Bending

In any crushing or bending test, the resulting decision must be dependent upon the prehardening by the working of the materials as a consequence of the test itself. Still it is conceivable that for a thoroughly standardized product (of definite method of preparation, chemical constitution, dimensions and heat treatment) such tests could have a significance from which conclusions as to the preliminary hardness could be drawn. But again, the time of carrying out such test has a most disturbing influence.

Brittleness and Ductility

Occasionally, in discussions on hardness, the term "brittleness" occurs, and in deformation of a permanent character, the term "ductility" is also often referred to; one may say a substance is hard and brittle, or hard and ductile. If brittle, its point of rupture is reached by the application of a very slight load beyond the elastic limit. For a brittle material, rupture and yield point coincide, for the state of aggregation is one in which decidedly limited displacements may take place, before the molecules become permanently detached from their centers of attractions. Materials of this nature may be conceived as being "keyed"* to the limit, so that the slightest slippage will cause rupture; certain brittle materials may have a fine grain structure so closely packed that it is conceivable that a state of no slippage could occur. This would account for the almost instantaneous rupture of certain classes of materials. In such cases, the cohesive forces are directly measurable by the yield point. Again, some materials are apparently brittle and plastic and in such cases they are brittle because of their rupture under suddenly applied or highly localized stress; whereas a constant force applied over a considerable period causes more and more flow. (An example of this is sealing wax).

There are also certain materials which are said to be soft, like chalk, in which very little force is necessary to separate the grains, still we know that chalk makes an excellent polishing material for hard material like quartz. This material is hard and soft from the microscopic and macroscopic points of view, respectively.

Materials are ductile because of the displacement possible of the

*By "keyed" is meant, that, minute fractured crystalline aggregates have been forced into positions between slip planes which do not permit said planes to further glide upon one another.

molecular aggregate of which they are composed. The extent of this displacement is fixed by the proximity of neighboring grains or aggregates. The greater this freedom, the higher the ultimate limit, and the greater the fatigue limit. (This is not used in the ordinary sense, but rather in the sense of the return of a material to its original state, after having been extended beyond the proportionality limit.) When fatigue passes into yield, an amorphous condition of metal is formed, which carries the interfering grains, causing increased strength. As a result of this, ductility is possible. Slip takes place between grain layers on plastic metal which acts as a viscous medium for them to ride upon, ultimately becoming "keyed," somewhat like the slippage of a pack of playing cards rendered sticky by molasses containing fine sand. The individual cards slip one upon the other, and finally set. Hardening as a result of work is an identical phenomenon.

Plasticity And Tenacity

In the sense here used, plasticity is the ability of a body to flow under pressure. Tenacity is the resistance that a body offers to such flow.

Most materials become plastic under great pressure maintained for a sufficiently great time. On the amorphous metal theory, plasticity should aid in making a material more tenacious for the reason that the crystalline or grain structure is decidedly much more minute than previous to the plastic deformation. If you choose, the intermolecular lattices are then filled with interfering material, which renders the possibility of slipping more remote, as a result of which a material becomes more tenacious and harder.

General Conclusions

From what has been said, it is evident that hardness is a very complex characteristic, being explainable only in terms of interatomic phenomena. No better evidence of this fact can be introduced, it seems, than the viewpoint of two eminent Englishmen, one a pure scientist, the other an eminent engineer.

Prof. A. H. Tutton, a crystallographer, says that the hardness of solid substance may be defined as the resistance offered by a smooth surface of the substance to abrasion. It is measured by a substance just being abraded or scratched by contact with a sharp fragment of another material whose degree of hardness is precisely known in terms of a conventional scale. In this process of measurements, the cohesive force of the softer material (which force is closely allied to hardness) is overcome.

Crystalline substances show different degrees of hardness in various directions. Along a cleavage plane they are less hard than in a direction at right angles thereto. These planes which are parallel to each other, are densely populated with atoms. Between them, the space density of atoms is much less. Therefore, cohesion is a minimum in planes at right angles to the cleavage plane. Particles are more easily torn away along the cleavage plane by shearing in this direction.

High specific gravity is generally accompanied by great hardness. (Lead and gold are exceptions.)

In space lattices, this means the closer the atoms are together, the denser the substance. Therefore, great difficulty is met with in overcoming cohesion, according to the laws of attractive forces between gravitating particles.

According to Sir Robert Hadfield, hardness as ordinarily defined is

the resistance to penetration. In general, a greater resistance is offered by materials already deformed than that required to produce the first permanent deformation in the same undeformed material. That is to say, there is a natural hardness and a deformation hardness.

No single value may be assigned to hardness in the general sense. It can only be expressed by a stress strain curve.

Hardness can be measured only by the yield point stress. (Except in such materials as pitch.)

No satisfactory method of measuring deformation-hardness, that is, the hardness of materials already deformed, has been developed. Scratch tests permit of comparison of this more or less definite property, but do not offer the possibility of numerical comparison. Other methods of measuring hardness determine the resistance of material deformed to varying amounts in different parts; therefore, it cannot be expected that they can agree among themselves or give a numerical value of hardness which bears a fixed relation to any of the others.

Brittle materials are subject to few or none of these complications of deformation hardness, and are therefore measurable as has been previously indicated.

Discussion of Dr. Hollnagel's Paper

Chairman A. E. Bellis: We are greatly indebted to Dr. Hollnagel for presenting this paper. He has certainly brought out the fundamental views of hardness testing. There will be further discussion of methods of hardness testing, but I think now is the time to make rational suggestions about the way of looking at hardness. I wish those that have questions would not hesitate to bring them up now.

Mr. E. E. Thum: The paper we have just heard discusses many features of hardness and from the standpoint of the steel treater and engineer, it seems to me that a great many of the problems that Dr. Hollnagel states can be pushed to the background. As he points out, the physicists are interested in the hardness of the ultimate crystal. A metallurgist or heat treater can satisfy himself as to the scratch hardness of any particular material by studying its microscopic character. I believe there is a simple attachment which he can fix to the stage of his microscope wherewith to draw a sharp point quickly across the polished surface. The character of these scratches varies from crystal to crystal, and the properties of each would vary depending upon whether he looked at it from the north or northeast. It is necessary to study these things. A piece of metal, however, is an aggregate of extremely small particles. Theoretically, a study of these fine particles which change with each breath of wind, gives us further insight into the aggregate relation depending on the amount and size of the particles. Every time one heats and quenches a piece of metal he gets varying conditions. On the other hand every time one gives it a little cold work, opposite effects take place. Consequently, the hardness which he is studying, certainly is hardness of that aggregate and is bound to vary with the physical condition of the aggregate. Therefore, to the practical man it may seem entirely superfluous to attempt a definition of hardness which will not bring the ultimate and desired end. For that reason, a great many variations in the conception of hardness of

metal have arisen and the practical man may very well question the desirability of eliminating the various shop tests of his, which may be rough, it is true, but are extremely valuable and give him information which to him is good.

Dr. H. P. Hollnagel: The material presented in this paper has been gathered from the shop, by questioning those who have had occasion to use so-called hardness testers for various purposes. To be sure I have made use of the scratch to show that it is not a suitable test for hardness. I have taken it up for a very good reason, namely a scratch penetrates only to a depth dependent upon the pressure applied to the work. I think, however, that the engineer is not interested in the scratch test for all purposes. I have not tried to bring out any definite conclusions as to what the character of the ultimate hardness definition or test should be. Rather have I left that point to this symposium, and I am very glad to have points raised, the better to get in touch with your viewpoint for to some degree I might be inclined to be more theoretical than practical, but I can assure you that I have as many practical problems in my work as does the steel treater and some of them have had to deal with hardness.

Mr. Troendly: If we take a piece of steel, say 10 or 12 inches long, make it into the form of a test specimen, so that you have a means of test for a slow application of load, and apply the load, in practically ten seconds, you reach the full deformation that that load will produce. However, let that load be applied for one day and it will go about 1 per cent further. You reach your full deformation in 10 seconds, which is the period between the application of load and permanent set, and is the time element taken by the material in being stressed until the entire indentation has been formed. A slow and prolonged deformation will occur, however, for several hours. It is only a matter of how long it is permitted to progress. I think this sheds more or less light on the time element.

Dr. Hollnagel: The two points which have just been brought up are indicative of several which I have in mind. In all, the time of application of the stress is of paramount importance. There is no question, but that in the matter of impact, the time element is even more important than in the case of more gradual deformation. It might be safe to say that one can apply a force of the order of magnitude of one million pounds to a specimen that has an elastic limit in the neighborhood of 150,000 pounds per square inch, and not cause rupture, even though the ultimate limit of the material had been passed. We approximated this, that is, the specimen and impactor were in contact for a period approximating 1/10 of a thousandth of a second, and the force approximated the order of magnitude indicated. In impact machines or those of rebound type, time is a very important feature as well as in the indentation type of machine.

Mr. A. L. Davis: I have been greatly interested in all the various remarks, and particularly in bringing up different machines that differentiate between materials of different hardness. A practical steel man will know that different machines do not give the same result. In the old times, the file was the first thing that the steel man thought of and probably it has been used more by the steel treater than any other, if we consider a period of thirty years back. Now steel treaters

are well aware that the file of certain alloy steels consistently understates the hardness as found in actual wear. The Brinell and Shore tests have come in and given us a more convenient and accurate method of measuring hardness of steel and probably the file will be used less and less, although on some products, it is the easiest way to determine it. I believe that almost every man who is concerned with the practical testing of steel products feels the want of some better method than any now in hand, or possibly the development of tables correlating the results from various methods so that the results of one method could be immediately interpreted for the hardness character of material in terms of other tests. The subject is one of such inherent difficulty that no doubt exists, from papers that you have listened to, that it is going to take the efforts of many people to bring about a satisfactory solution for the practical man. I wish I had the data that could be submitted for correlation tables, but I think it is going to be necessary for us to start from the bottom and compile it in order to make accurate comparisons.

Chairman Bellis: We have a paper that has been submitted by Mr. German, metallurgist of the Henry Disston & Sons, Inc., Philadelphia, Pa. Mr. German is not here. I would like to continue the discussion after we have heard Mr. German's paper, that would bring up one or two subjects that have not been touched, I will ask Mr. J. J. Curran of the Henry Souther Engineering Company if he will read Mr. German's paper.

Mr. German's paper.

TESTING OF METALS FOR HARDNESS

By H. M. German

Definition of Hardness

HARDNESS is the ability to withstand abrasion or resist penetration. This is the definition that has been accepted for the term of general hardness. In recent years, there has been a tendency to provide more specific terms to steel, as follows:

Initial Hardness is the hardness obtained by quenching.

Temper Hardness is the hardness obtained by tempering initial hardness.

Case Hardness is the hardness of the surface of steel obtained by carburizing and quenching or caused by overheating in grinding.

Red Hardness is the property of a cutting tool to retain its hardness when operating at a red heat.

Types of Hardness Testing Machines:

For many years, hardness had no fixed measure but only a comparative value. For example, metals were compared with others of similar hardness in the same manner as minerals were compared to a standard; which ranges from talc, which is so soft it can be cut with a finger nail, to a diamond, which is the hardest known substance. This method was very unsatisfactory as the values could not be used in specifications (if they were used in the earlier days) for they had no

definite value. In order to provide a measure for hardness, many types of apparatus were designed. They may be roughly classified as follows:

1. Those measuring the resistance of metals by scratching or abrasion. Turner's sclerometer, which was designed to test the hardness of foundry irons, consisted of a balanced arm having a pointed diamond fixed on one end, so that the point of the diamond rested upon the polished surface of the piece to be tested. By moving a sliding set of weights along the arm, a pressure is reached when the diamond makes a standard scratch on a standard surface. The weight, in grams, on the diamond point is taken as a measure of hardness. Various modifications such as using a constant pressure on the beam and measuring the width or depth of scratch, and replacing the diamond with a hardened steel cube, are also used. This type requires a standard surface and can be used for testing all kinds of metals.

Scratching the surface of cutting tools, such as files, with a test piece of given hardness has been used for years as a commercial test to sort out those that are too soft and too brittle.

2. Those using the resistance of metals to cutting. Keep's drill test was developed to test the hardness of castings. In performing this test, a standard piece was placed under a drill of fixed size and grind and operating with a fixed speed and pressure. The number of revolutions of the drill to pierce the piece was taken as a measure of hardness. This type also requires a standard piece for testing but can only be applied to metals which are soft enough to drill.

Before passing on the next type, the file as a testing medium should not be overlooked. While only giving comparative values, the file test is the quickest, easiest performed, and, in many instances, the most reliable test for hardness and detection of decarburization that the heat treater has at his command. This applies particularly to testing hardened articles before tempering. In many plants hardened articles are file tested to determine the amout of tempering necessary. The file test does not require a standard piece for testing and the articles tested are not damaged.

3. Those using the resistance of metals to indentation. The earliest machines of this type consisted of a weight having a hardened steel knife-edge or holding an indenting tool of pyramidal or conical shape that was caused to drop, by gravity, on the piece to be tested. The depth or width of indentation was taken as a measure of hardness. These machines led to the development of the Brinell tester. This instrument presses a hardened steel ball of given size with a constant pressure on the piece to be tested. The standard size ball is 10 millimeters in diameter and the pressure, 500 kilograms for soft metals, such as lead or babbitt and 3000 kilograms for harder metals, such as iron and steel. The diameter of the depression, measured in millimeters by a microscope containing a calibrated scale, is taken as the measure of hardness. The practice at some plants is to use the diameter as the hardness measure, while at others, the Brinell hardness number, found by dividing the pressure in kilograms by the area of the depression in

square millimeters is preferred. The hardness number need not be calculated as it can be found by comparing with a chart furnished with the instrument. Various modifications of this type such as using weights instead of hydraulic pressure, and measuring the depth instead of diameter of impression are used but the principle remains the same. The Brinell method does not require a standard piece for testing, but it has its limitations as it is not applicable to brittle substances or those that cannot stand a permanent deformation, to thin sections, or to pieces where the depression hole would spoil the finish of the article.

The Rockwell test is a modification of the Brinell. It consists of pressing a hardened steel ball or a diamond cone, of 120 degrees angle, into the article to be tested and measuring the depth of impression with a dial micrometer. The size of impression is much smaller than in the Brinell test as the steel ball is only one-sixteenth of an inch in diameter and the maximum major load is only 150 kilograms when using the diamond cone and 100 kilograms when using the steel ball. Arrangement is also made to apply a smaller load of 60 kilograms, if desired, for soft metals. The method of applying the Rockwell test is different from the Brinell in that the total depth of depression from the surface is not measured. In making the Rockwell test, a minor load of 10 kilograms, regulated by a spring, is first applied to the ball or cone; the micrometer dial is then set at zero, or at a fixed point and then the major load is applied. Upon releasing the major load, the depth of impression caused by the major load only is indicated on the micrometer dial. By using a special reading glass, the diameter of depression of a steel ball can be read the same as in the Brinell test. The Rockwell test does not require a standard specimen, it does not spoil the finish of the article tested, except on very high polished work, and it can be used on much thinner sections than the Brinell (.010 inch for iron and .015 inch for brass), but it cannot be used for testing thin sections that are brittle or cannot stand a permanent deformation.

4. Those measuring the height of rebound of a weight when allowed to fall from a given height upon the article to be tested. The scleroscope invented by Shore, utilizes the above principle. It consists of a cylindrical weight one-fourth inch in diameter by three-fourths inch long having a diamond striking point, slightly spherical and blunt, about .020 inch in diameter. The weight is allowed to drop by gravity from a height of ten inches, through a vertical graduated glass tube on the article to be tested. The height of rebound is measured by noting the highest point of the weight against a graduated scale in back of the glass tube. Articles to be tested are placed upon a hardened steel anvil; the tube is clamped tight against the specimen, and the weight released by an operated spring. For testing large specimens the tube can be removed and attached to a swing arm or held in the hand. The scleroscope does not require a standard piece for testing; it does not spoil the finish of the article to be tested; it can be used on very thin sections and by holding in the hand or swing on very large sections.

Selection of Hardness Testing Machine

With the present and increasing competition among manufacturers, it

is absolutely essential that their products be turned out uniform and up to a given standard for hardness or temper. The product can be checked only with a standard by means of a testing machine that will give reliable values. File tests, are fairly satisfactory in certain cases, but for example, if a heat-treater was told to temper an article so as "to file readily" a term commonly used, it would not have a fixed value or even within close limits. Also the property of the article to "file readily" would be greatly influenced by the type of file used and the ability of the operator using it. Hardness values must be fixed not only in one plant, but they must be interchangeable so that manufacturers and customers can deal with each other in definite terms and thus draw up mutual specifications.

The principal hardness testing machines used are the Brinell, Rockwell, and scleroscope.

For testing articles within its limitations, the Brinell machine has, for years, been recognized as the standard. This machine is the most accurate and the most reliable that has been developed. It is always operated under a constant pressure and if care is taken to apply it gradually and to maintain it for a fixed period, consistent results will be obtained. Measuring the depression by means of a microscope containing a calibrated scale is accurate and possesses the advantage of having the operator observe the depression for roundness. The machine is exceptionally strong and rigid and will hold its adjustments for years.

The Rockwell machine is used to apply a modified Brinell test to articles that are too thin to be tested by the Brinell method. The manufacturers of the Rockwell machine definitely state that the machine will "test on a comparison basis." This should be remembered as the Rockwell machine does not read direct in terms of the standard Brinell. However, it is not difficult to test a number of pieces of a given steel having a hardness range from soft to hard on both the Rockwell and Brinell and plot a curve that will show a direct comparison of the readings. This curve will only apply to the class of material from which the readings were made. The physical properties of high carbon, low carbon, and alloy steels vary with the same hardness as measured by any hardness testing machine. Therefore, it is impossible to compare hardness results between two types of machines on one class of metal with a chart made with another; for example, comparing high carbon steel with manganese steel. Contrary to what has appeared in print recently, there is a definite relationship between hardness readings obtained by either indentation or rebound methods, and physical properties which are affected by hardness, such as: machining qualities, resistance to wear, etc. when comparing like articles under like conditions. It is folly to compare the machining qualities of steel versus aluminum by hardness tests, or the resistance to wear of manganese steel versus carbon steel, but there is a distinct relation between the machining qualities of a given type of steel having different hardness readings, and of aluminum of different hardness readings, and likewise a distinct relation between the resistance to wear of pieces of a given type of carbon steel having different readings, and pieces of a given type of manganese steel having different readings. Comparison readings can only be made with like articles. This applies to any type of hardnesss testing machine.

The scleroscope is used to test all types and sizes of metals by a comparison method. It has just been stated that comparison readings can only be made with like articles. There is an additional limitation placed upon

the scleroscope. Comparison readings can only be made with the scleroscope when testing like articles under like conditions. Some of the conditions that effect scleroscope readings are: size or thickness of the piece tested; flatness; condition of surface such as rough, ground, or polished; size and hardness of anvil under the piece to be tested; and whether the scleroscope tube is clamped tightly or held lightly against the piece to be tested. It is not possible to accurately compare the hardness of a thin piece of spring steel after it has been tempered with a like piece after it has been ground, or with a like piece that has been ground and polished. The effect of mechanical work in this instance causes the readings to become higher. It is possible, however, to compare readings of like pieces under like conditions. If this simple axiom was understood and followed, the following extract from a criticism on hardness testing would not have appeared recently in a prominent trade journal:

> "Whoever heard of hardness testing when wearing properties are what are really wanted? If the wearing properties are involved a test for resistance to wear, which has absolutely nothing to do with hardness, is the only information on this point that can possibly be obtained. Why blame *hardness tests* for the fact that there is no relation between 'hardness' and 'resistance to wear'? We might as well blame the Hudson River for flowing into New York Bay instead of San Francisco Bay.
>
> "The sentence, 'Hardness testing would tell us that steel gears are the best', is without sense in view of the well-known facts just mentioned. Since the scleroscope gives a higher reading on soft rubber than on hard steel, would anybody presume that gears of soft rubber would be 'the best'?"

There is a condition that will greatly effect the readings of a scleroscope and that is a decarburized surface, but why condemn the scleroscope for telling the truth? The steel-treater should know if the steel he is treating is decarburized and if the scleroscope indicates this condition, which it does, it is an aid in his work.

Conclusion

In conclusion it is hoped that this article will have shown:

1. That no one machine is adaptable for testing all kinds of work;
2. That the machines will give comparative results only when testing like articles under like conditions;
3. That reliable results can be obtained only by working under fixed conditions and observing necessary precautions;
4. That readings obtained from one machine can be changed to terms of the other machines.

Discussion of Mr. German's Paper

Chairman Bellis: Mr. Curran has done some interesting work on hardness testing problems, and I would like at this time to have Mr. Curran state his experience.

Mr. J. J. Curran: In connection with the Brinell test as described here, we had occasion recently to examine several different makes of Brinell balls to determine the effect the method of manufacture, etc. had on the readings that are obtained on a given piece. The samples we had were from four different manufacturers. One of them was a ball made especially for Brinell hardness tests—a carbon steel ball of

foreign manufacture and we wanted to determine definitely its suitability for the Brinell test. For comparison, we selected some special balls of chrome tungsten steel made by the Hoover Steel Ball Co. and two makes of chrome carbon balls made by two different manufacturers. We happened to have the latter three in use in our own laboratory. We had a very few of the carbon steel balls that started the tests, and we had very little idea at the start just how we were going at it, but we proceeded first to examine all types of balls, as we would have, were they intended for ball bearings. While that examination may not have much bearing on the use of a ball for the Brinell test, we decided to obtain this record for any information or service it might give later. It was interesting to notice that with respect to one very important feature in the life of a ball bearing, i. e., surface, finish or polish, the ball which ultimately showed up best for the Brinell test had the poorest surface. It shows that some of the standards that apply to bearing service do not apply to this test. The usual surface examination and measurements were made to determine sphericity and absence of flat spots, also scleroscopic tests were made under as near standard conditions as we could get. The foreign carbon steel ball was the hardest of all. We also ran crushing tests, that is, three ball tests, and the results were extremely variable. The most important part of the test was a comparison that we made as follows: We took two discs of chrome tungsten steel, surface ground and hardened them, and then tested three balls of each type, twelve in all, by applying a Brinell load of 3000 kilograms to each ball (one at a time), between the two hardened discs. We were able to test all twelve balls between the same two discs, merely adjusting the discs so that each succeeding impression would not strike the others. The surface of the discs were carefully polished and then lightly etched before the impressions were made. The diameter of the depression was measured in the usual way with a Brinell microscope and it was found that a given ball would always produce the same size depression on both discs, indicating that the discs were quite uniform in hardness. It was interesting to note that the ball that showed the highest scleroscope hardness also gave the smallest impression on the two steel discs which would indicate a higher hardness in the disc, supposing you were testing the disc rather than the ball. The most important feature of the test was the measurement of the deformation of the ball. The balls were all very carefully measured to one ten thousandths of an inch. After applying a load of 3000 kilograms, the balls were removed and by feeling with a micrometer, we were able to find the flat spots. The reduced diameter of the ball across the flat spots was measured, and, expressing it in terms of the percentage of the original diameter, we found that the ball of the highest scleroscope, deformed the least in the test, also indicated a higher Brinell hardness for the two discs. It would, therefore, seem that in testing hardened steel, it is desirable to obtain the hardest Brinell ball possible in order to get the figures which approximate the true Brinell hardness. A soft ball deforms under load and will give a large shallow impression indicating a low hardness. We obtained differences that ran up in the magnitude of 100 points in the neighborhood of 600 to 700 Brinell, hardness number depending on the type of ball used.

Mr. M. A. Grossman: How much were the balls deformed by the test?

Mr. J. J. Curran: I think the deformation amounted to between 0.3 and 1.0 per cent reduction in the original diameter, that is, the smallest measurement I could get across the flats would be from 0.3 to 1 per cent less than the original diameter of the ball.

Mr. S. Tour: The idea of the committee as I understand it, is to develop one particular hardness test, if such a thing is possible. As far as I can see, each particular hardness is a thing in itself, which measures something different. It is obvious that the Brinell test is different from the scleroscope test. To my mind, it is also obvious that we do not want a hardness test of one particular kind and abandon all the rest. The man in the shop using a tool does not care whether that tool is a certain scratch hardness or not. All that he wants to know is whether or not the tool will cut. Perhaps a scratch hardness has something to do with this property. I do not believe that it is possible to get one hardness test that will answer for everything that we want to test, but we have too many tests. It is unfortunate that we call them all hardness. I cannot imagine one type developed to correlate with another. We cannot call Rockwell so much Brinell, and we cannot call Brinell so much Rockwell. We can possibly develop other tests for specific uses which will be better than the tests we have at present. I doubt if we can develop one test that will eliminate the present tests or find any one kind of hardness that is going to answer for all, whether we call it hardness or something else. I have not been able to think of a good definition for hardness or for the different kinds of hardness. One speaker said something about correlating results of one hardness test to results of another. We cannot compare scratch with Brinell hardness. They are two different things, but we must decide what the proper scratch hardness is, and what it designates or some other thing to take the place of scratch hardness. We must decide what a Brinell test is and we must not forget the time element. We must decide what the Rockwell hardness is, what it measures, and if it is of value, use it. Then there are a number of different types of hardness which are similar. Some should be ruled out. In other words, if Rockwell hardness measures almost the same thing as Brinell hardness, and measures it better than Brinell hardness and answers the purpose better than Brinell, take Rockwell.

Mr. A. Hungelmann: Would it not be possible to formulate some instructions as to how to use different machines? You speak so much of the time element. I think the time element is just as important with metallurgists. The hardness is only one of the matters discussed at this convention, and no doubt many of us have not given the subject very much thought, but we would all be benefitted by a committee ruling as to the proper way to apply different tests for different purposes. I think we would all like to see that published.

Dr. Hollnagel: It would undoubtedly be possible to give such information with regard to a machine like the Brinell or Rockwell, but it would be quite impossible to offer anything with the present type of scleroscope. Before we could begin to tell that, we would have to make changes in the scleroscope. Before comparative tests thereon may

be had, one would have to make the impact for different materials the same. This could be done by reasoning along the same lines as one of the previous speakers referred to, that is to establish a specimen size such that the time of propragation wave in the specimen is the same. Furthermore, rebound will take place in approximately this time, and if the energy of the impactor is sufficient to exceed the elastic or ultimate limit, then one is still in the dark for some of this energy has gone into the indentation of the specimen and is lost as heat. This cannot give a true measure of the material as ordinarily taken. Resilience of deformed material rather than the resilience of original material is tested.

Mr. A. Hungelmann: I might ask Dr. Hollnagel if he thinks it is an impossible job to bring about these conditions?

Dr. Hollnagel: I am very glad to state that we have been thinking along this line. We hope it will be possible to make the time element the same in impact and rebound devices, and while we are not ready to publish such information, we have it in mind and are giving it very careful thought. I believe it can be done ultimately, but it is premature to make a positive statement at this time.

Mr. A. D. Flinn: I am not a steel treater or even the brother of a steel treater, so you must not take my remarks too seriously, but I do wish to congratulate your chairman and Dr. Hollnagel and the other members of the committee on the excellent work that the committee is doing. It is the kind of work which serves as an example of the thirty or forty committees working along similar practical lines. As I have been listening to Dr. Hollnagel's paper, and also your discussion, two words have run in my mind repeatedly, which no one here has used. One is relativity and the other is progress. Please do not think I am referring to Dr. Einstein's theory, for I know nothing about it, but rather that the engineer is always dealing with the relative. The physicist is a pure scientist, and deals with the absolute and basic fundamentals; but if our reasoning is not based on the last conception of the physical facts we are going to be misled in carrying out our tests or any other engineering processes. The word hardness is a common English word, and like all such words, it has certain meanings which we carry almost automatically into our so-called technical uses of these same terms. It may not be possible to meet the suggestion of the speaker, but I think it would be fortunate, if the committee could invent a new term. Let us not be afraid to do what the doctors and some of the other scientists do, take a term from the Latin or Greek, a word that will embody the results of the studies of our committee. I think it may be possible that it will not be one term but several terms which will eventually take the place of the word hardness. This discussion of scratch test impressions calls to mind a question concerning the meanings of common words. Some years ago a friend of mine, who was an amateur photographer, secured samples of a new developer with instructions which he followed, and got very unsatisfactory results. He tried again and again and being satisfied that he had done the best he could with the English language, and the materials, eventually went to a demonstration office, and asked to be shown how to use the developer. Among the instructions were these words "use a low gas flame," in a certain part of the process. He watched the man

start and noticed the size of his flame. He said, "You need go no further, if that is what you call a low flame." My friend had been using a flame about one-quarter of the size which the demonstrator used. This is an example of the meaning of a common English word. I am thinking the same is true of our scratch test. Furthermore, what was satisfactory so many years ago is no longer satisfactory because we have progressed. The method of 20 or 30 years ago can no longer meet the refinements of today, and we must change our terminology.

Mr. Rockwell: In dealing only with metals, ferrous and non-ferrous, according to our various ideas of what hardness is, we all know that no matter on what machine tests are made, we get high readings when we have greater hardness. I would like to ask Dr. Hollnagel whether or not he thinks that the time element can be made relative? Is it less with the hard than with the soft materials, and does it form a regular curve?

Dr. Hollnagel: That would have to be determined and it would unquestionably follow some form of regular function. For materials which are flat, the time element would be less than for materials which are rough. This would have to be investigated before one could tell definitely what should be the actual time element. There is as I understand it today, no definite specification on time in any of the material testing devices throughout the country. If you make a strength test for example, you turn the handle of a testing machine and await the drop of the bar. You use your own judgment. In some laboratories, of course, the one in charge stands alongside and says what is to be done. If the same specimen that has been run up in 1½, 2 or 5 minutes is run up in a time considerably less than that, the elastic limit will go up quite considerably beyond what it ordinarily is.

Mr. Rockwell: Would not that be a certain line of work for the committee, say, simply to specify 20 seconds for soft metals for the Brinell test, and 15 seconds for hard metals?

Dr. Hollnagel: It would be rather an unfortunate thing to have a range of time for different degress of softness or hardness, that is, if one could standardize on the time of application of stress and have the entire scale for a given instrument and kind of material, then it would seem that a correct comparison could be had straight through. The other plan would give so many different results that a given hardness would mean little. It would seem better to standardize on the time for a material and let the load be variable for material. Of course, that brings up the question as to size of ball for a given load, but certainly we can correlate the results obtained for different sizes of ball, with comparative ease. It is only a question of working until a relationship is arrived at which is desired, and if proper time limits be agreed to, proper correlation should be possible. Until that information is at hand, one is quite in the dark.

Mr. Beamont: It is my opinion on this testing that it is misleading to believe any of the information gotten by applying testing machines to any definite work; the conditions alter so. For instance, the Rockwell machines are absolutely unfitted on certain classes of work, such as forgings, owing to the surface conditions of the steel; a scleroscope is likewise absolutely unfitted for such work because it is impossible to get data. A file as a testing machine is, I believe, the most reliable at

present. Another method of testing is the Brinell. As regards terms of hardness, I think we have worked this down to a very fine point, but possibly, Rockwell and Brinell all really do define the self same thing. I think the difference in the machines in their readings is simply because they read differently something proportional to the same properties and therefore cannot get the same results. Arriving at a result by rebound cannot be the same as by a penetration of a ball to a 1/16 inch. It may be that we will need many kinds of hardness for we are arriving at different conclusions by different methods.

Dr. Hollnagel: I am in entire accord in regard to being able to utilize instruments on rough castings; when it comes to the question of standardizing hardness tests of any sort, it will have to be done on surface of comparable character, prepared the same; then will tests be comparative. One should neither polish the surface nor leave it rough; the surface should be somewhere between the two in nearly every case. As to all three machines measuring the same I am afraid I will have to take issue. A scleroscope does not measure the same thing that a Brinell or Rockwell machine does. The scleroscope returns to the tup of a certain amount of energy which ordinarily in testing materials is spoken of as the energy due to resilience and which is certainly quite a different thing from what happens when one drives a piece of "hard" metal into a specimen. Take a Brinell depression specimen, cut a section across it, polish and etch it, and examine it under the microscope—a very interesting field is open to you. You will find successive layers of compression just as clear there as you do boundaries in different stages of steel. This does not result in scleroscope test when the material does not show marked permanent set. It does result to a very minor degree when slight permanent set appears.

Mr. G. W. Walker: I have noticed at different times statements in regard to time element in use of Brinell machines. One statement was that the load should be applied for a minute, another for half a minute, etc. I am wondering if anyone has determined what difference is made in the hardness number for varying periods of time that the load is applied, whether a minute or half a minute.

Dr. Hollnagel: We have not made any tests which would make possible an answer to your question, but we have satisfied ourselves that time and application of stress do affect the number. We probably will in the near future do something along that line to definitely establish it. I might say also that any type of machine, which applies the pressure in a pulsating manner would not be anywhere near as good as the one that applies a constant load. They are also those which provide pressure by centrifugal pump; this reduces the magnitude of the impulse and more nearly approaches constant duration of stress.

Mr. Walker: In consideration of this whole matter of hardness, it seems to me that first we must agree as to the definition of the term hardness and having agreed, we must define all of the conditions under which the tests must be made, such as time, pressure, etc., or whatever is necessary, and then go to work and construct a machine accordingly. It is only after we have defined conditions that we will be able to get any reliable results. I remember seeing in Edison's "Engineering Steels," a statement that a piece of drill rod properly hardened and with

the end ground off square, was a much better means for determining "file hardness" than a file.

Mr. Beamont: This test has been carried out in the plant of Indianapolis Ball Bearing Co.

Dr. Hollnagel: Can you say how nearly reproducible the results are after each grinding or for different drill rods?

Mr. Beamont: No.

Dr. Hollnagel: Material is very apt to change from grinding to grinding. You would have a different character as you went along. If the material is not ground enough, you can put amorphous material across the surface and by too fine grinding, change the character of it, but if it is comparatively rough and satisfactory in this form, you will probably be fairly successful.

Unannounced Speaker: Answering the question as to whether it makes any difference as to the time of load in a Brinell test, would say, that about five years or more ago I was experimenting with some rail steels and investigated that question to the best of my ability and found that the irregularities in the steel dies which I was using caused a greater difference in the depression than any difference which I could find due to leaving the load on 15 seconds, 30 seconds, 45 seconds, a minute or even a day. However, fairly large variations could be had by pumping up quickly or slowly. Mr. Archer of the Aluminum Co. of America recently told me of an instance where he took a very well made and uniform piece of aluminum alloy, fairly soft, Brinell A perhaps, broke it up into several parts, sent to several laboratories which reported hardness plus or minus 80 and 20. He thought the difference was due to the difference in speed at which load was applied. If in A type Brinell you raise the rate very rapidly you will get more than the theoretical thousand, and consequently a larger depression.

Mr. Curran: In connection with what the previous speaker has said, I wonder if some of the variations were not possibly due to flatness of the balls used by the different men. I have found this condition in plants that I have gone into. For hardness testing work, we try to make conditions ideal. I have been in plants where they use the ordinary hydraulic type of machine, and I have found that it is rarely possible to check results. The average ball in daily use is not round. Some show signs of severe wear, having been used so often. It is folly to take a ball and use it for soft material, then hardened material, and then back to soft material and hope to check previous results with it. In connection with Mr. Walker's question about the effect of time, I recall having heard a paper on this subject, although I am not certain at what meeting I heard it, but I believe it was the last meeting of the American Institute of Metals in Boston some five or six years ago, in which it was stated that in soft materials, it was possible to get variations in the size of the impression by holding your load for different lengths of time up to fifteen minutes. In our regular practice I doubt if any variation in time between fifteen seconds and a minute on ordinary steel will produce differences in observed hardness. It may produce a difference in the reading, which the average Brinell microscope would not indicate, being within the limits of error in reading.

Chairman Bellis: As a rule, as carried out, Brinell tests are not closer than ±5 per cent, according to Foss and Brumfield.

Mr. H. B. Northrup: I believe I have a point of view which some are overlooking in the question of hardness, whatever definition you may have for hardness. There has been an article written recently which stated something about the specifications which did not specify. In my opinion, there are two kinds of hardness; hardness which you will desire to use in writing a specification for material to customer and hardness which you want to use in inspection. I believe they are entirely two different things. Taking the first hardness, which you wish to use in specifying a certain hardness on a certain piece for a certain customer, who may specify material is to be 300 Brinell hardness number. In that case, I believe it is highly desirable that the ball be standardized so that you get a certain definite standard hardness of ball to be used in a testing machine, specify the load that is to be applied and the duration of the load. On the other hand I believe that the various methods of hardness which have been devised and which are in constant practice, as an inspection method has its practical application; for instance, a man may wish to test a piece by what he terms hardness for inspection purposes by the file. Agreeing with Dr. Hollnagel, I believe that the file test should be standarized in the shop where you wish to use it as an inspection method. That file test used on that paricular piece is probably the only test that can be applied. For instance, I know of some automobile work where they specify the size and kind of file. They also specify that the file be used with moderate pressure and if the piece is harder than the file, the file will be marked. I have seen inspection methods where a file is used, where a 200-pound man laying on a piece of steel clamped in a vice will call that piece not file hard if he can at least scratch it. If he would use common sense in applying his pressure, and notice his file he would have reported differently. Grinding off material will have some direct bearing on the resulting test. Am not inclined to believe in the use of drill rod as a testing medium. Am inclined to specify for inspection purposes a certain file test piece with a file and in making the test observe the file as well as the piece. If the piece for inspection purposes withstands a file used under the directions of common sense and that piece is to be used in a certain part of a given machine and withstands the test, that is all you desire. On the other hand, if you are going to write the specifications for the use of a certain given testing instrument you must standardize it.

I had occasion recently to make some tests which did not agree with the mill and we rejected the stock. The mill came back and wanted to know the rate of application of the load. This subject has been raised this morning numerous times. We gave them the rate of the application of the load, and next coming down to a common process, they checked our results and substantiated our rejection of that stock. Their rate of application was different from ours, and we were working at, you might say, opposite ends. Something can be offered in specifying hardness. We have recently installed in our shop the Rockwell machine. We have the latest Brinell Alpha machine which I thought was pretty good. We have the scleroscope and we have files. There is a lot of beating around the bush about specifications that do not specify, and

bringing up my original point, there are two kinds of testing for hardness, one for specification and another for inspection.

Dr. Hollnagel: I think Mr. Northrup's specification of putting common sense into the test is rather an elastic one, but I think he brought up some very good points and am glad they have been called to our attention. We are making some apparently destructive criticisms, but we are trying to get to the bottom of limitations on present processes. It is necessary to take a somewhat extreme viewpoint.

Mr. H. B. Northrup: As an illustration of that point of the use of the scleroscope for an inspection: During the war we had to specify for inspection purposes certain scleroscope hardnesses on certain pieces of carbon steel. In one part of the light Browning rifle, we had a certain scleroscope hardness test, part of the instrument was not standing up. In discussing this with Mr. John Browning he stated that you don't need a scleroscope to tell you what the correct hardness of that piece is. All you need is a vise and hammer and common sense. You can't break every piece, however. We used a scleroscope and obtained the nearest reading we could to a piece he said was correct for the gun.

Mr. G. W. Keller: I have noticed some exceedingly critical remarks on method of testing one against the other. I think for the work to be a benefit as a whole, we must put aside our personal criticisms of methods, recognize that the principle of Brinell and Rockwell is slightly different from the scleroscope, but each of them have one fundamental method which we must develop. We must take what the scleroscope has to give us and not see its limitations but what we can do to perfect each machine.

Dr. Hollnagel: It is a pretty well known principle that before you can construct you must destroy. We, therefore, must give destructive as well as constructive criticism. We do not aim to make decisions on behalf of any type of so-called hardness tester. In regard to Mr. Northrup's common sense, the committee is not a psychological body and cannot analyze common sense. Common sense is a characteristic of the individual. Moderate pressure applied to a file. What is moderate pressure? It may mean one thing to a child, another thing to a woman, and so on. These terms are purely relative. We cannot deal with any specifications of such indefinite character. Give us something in terms of which we can define terms such as moderate pressure and common sense and our committee will be only too glad to give it consideration.

THERMAL TRANSFORMATIONS IN SOME CHROME-VANADIUM STEELS[1]

By J. S. Vanick and W. W. Sveshnikoff

Abstract

A study of the movement with changes in composition, initial temperature and rate of cooling of the thermal transformations in a series of chrome-vanadium steels was made, and correlated with difference in hardness and microstructure, to indicate possible changes in constitution. A chrome-vanadium composition of the forging type (i. e., .30-.40 per cent carbon; 1.0 per cent chromium and .18 per cent vanadium) was used as a pivoting composition. One of the important elements was varied while the remaining two were kept constant. Carbon was varied from .16 to 1.16 per cent; vanadium from 0.0 to .65 per cent; chromium from 0.0 to 21.0 per cent. Three additional steels were added to illustrate the influence of the .30 to .40 per cent carbon range and the effect of the common impurities, namely manganese, silicon, etc.

Increasing the carbon content from .16 to 1.16 per cent, lowers the positions of the transformations; which remain, however, some 10 to 30 degrees Cent. above those for the corresponding alloy-free, steels. Ac_2 occurs above Ac_1 in the low carbon steels. Increasing the initial temperature from 850 to 975 degrees Cent. lowers Ar but 12 degrees Cent., indicating that the solution of the elements is practically complete at 850 degrees Cent.

Increasing the vanadium content from .025 to .65 per cent, produces a small displacement of the transformations. A-1 is raised approximately 5 degrees Cent. for each 0.10 per cent vanadium. A-3 is obscured in the thermal curves but revealed in the hardness curves. Thermal and hardness data indicate that the solution of the element or its compounds is accomplished between 850 and 900 degrees Cent. Cooling from the latter temperature and 975 degrees Cent., does not displace the Ar transformations.

Increasing the chromium content from 0 to 21.0 per cent produces a gradual rise in Ac_1, effecting a junction with Ac_2 at .75 per cent chromium, and Ac_3 at 3.1 per cent chromium; continuing its rise to 7.7 per cent chromium, then remaining constant. Meanwhile Ac_2 remains constant to 7.7 per cent chromium, then begins to fall. These facts are explained by supposing the chromium enters the carbides until approximately 7.7 per cent has been absorbed, whence the excess passes into the ferrite.

The split transformation appears feebly, at 2.0 per cent and strongly at 7.0 per cent chromium, for the cooling rates used. Increasing the cooling rates or raising the initial temperatures suppresses or lowers the transformations. These effects, upon cooling from fixed temperatures at increasing rates, are attributed to the re-

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tarding action of chromium in solution while the effects produced by cooling from higher initial temperatures are attributed to the dissociation of carbides and the distribution of their components.

The structures which accompany the various thermal changes indicate that the combined Ar_{3-1} transformation occurs in segments when Ar' and Ar'' appear as distinct inflections.

IN THE course of an investigation of a series of chrome vanadium steels, it became desirable to determine such physical characteristics as some of the methods of thermal analysis would yield. The range of influence of certain of the variables involved in the thermal study is quite broad, on account of the sensitivity to thermal changes of some of the steels. The records of thermal behavior are for this reason, quite necessarily limited to the particular phenomena under investigation. It is the purpose of this paper to present some of the results obtained in the thermal analyses of a series of chrome-vanadium steels with the object in view of adding to the information now available.

The steels selected for this purpose consisted of the series listed in Table I. As indicated in the table, the series lends itself readily to a division into 3 groups each of which comprises a variation in the concentration of one of the alloying elements. Inasmuch as manufacturing practice limits the commercial application of these steels, the range of compositions were chosen to lie close to those of available commercial steels.

The steels (20) which were used in the following experiments were made by the electric furnace process. The necessary ferro-alloys were added in the ladle, to the liquid metal which was subsequently cast into ingots and rolled into bars. Specimens for thermal analysis were cut from bars which were previously annealed at 1000 degrees Cent. to remove possible thermal effects which may have been introduced in the preparation of the steels.

Thermal curves were obtained by the inverse rate method with the apparatus (2) available for this purpose at the Bureau of Standards. The samples used in these tests were roughly 10 x 10 x 2 millimeters in size, slotted to the center to receive the thermocouple. The temperature gradient throughout a specimen of this size is negligible. The heating and cooling was conducted at a rate of .10 to .16 degrees Cent. per second. This rate is a normal one for an alloy-free steel of a corresponding carbon content. More rapid rates would cause an appreciable displacement of the transformation in certain of the steels. Cooling curves were taken immediately after the maximum temperature for the particular specimen was reported. The time interval during which the specimen remained at the temperature from which cooling began was consequently very short.

The details of manipulation described above, are mentioned in view of the sensitivity of steels of this type to small variations in the initial temperature, time at temperature and rate of cooling. It was desired to maintain conditions as nearly uniform as possible in order that the influence of changes in composition and to some extent the effect of varying certain physical factors might be observed.

In some cases several heatings and coolings were made for each curve

and the results plotted as shown in the following figures. Each point in the curves represents an individual observation. The slight roughness which the curves show in places is caused by small observational errors

Table I

Compositions of Chrome Vanadium Series of Steels

Mark	C.	Mn.	P.	S.	Si.	Cr.	V.
Carbon Group							
11	.16	.55	.023	.023	.34	1.03	.20
1	.30	.68	.012	.024	.26	.93	.18
12	.58	.68	.011	.017	.23	.73	.18
13	1.16	.55	.022	..018	.20	1.06	.20
Vanadium Group							
14	.40	.53	.018	.023	.18	1.05	.025
7	.37	.52	.018	.018	.20	1.05	.07
1	.30	.68	.012	.024	.26	0.93	.18
9	.37	.55	.018	.019	.18	1.07	.31
10	.27	.34	.025	.011	.29	1.24	.65
Chromium Group							
A	.33	..	...	.007	.009	...	..
B	.34	.55	.030	.032	.14	...	..
C	.40	.75	.010	.034	.22	...	..
2	.38	.39	.017	.022	.27	.04	.19
3	.29	.53	.015	.011	.16	.51	.28
1	.30	.68	.012	.024	.26	.93	.18
4	.31	.48	.011	.011	.12	2.01	.34
5	.33	.37	.028	.013	.26	7.70	.18
6	.42	.35	.025	.009	.06	14.40	.18

which would extinguish each other if the differences were balanced.

Thermal Transformations in the Carbon Group

Transformations Upon Heating

Fig. 1 shows the influence of carbon upon the thermal transformations in a steel of a typical chrome-vanadium composition. A comparison of the curves representing specimen B of Fig. 2 with those of steel No. 1 of Fig. 1 illustrates, directly, the raising of the Ac and Ar transformations with the exception of A-2 by the presence of chromium and vanadium. The influence of chromium in this respect, has been observed by Osmond (1) and confirmed by others. A similar property has been associated with the addition of vanadium.

The increase in carbon is accompanied by a gradual lowering of both Ac_1 and Ac_3, but the increased degree at which the latter is lowered results in its combination with Ac_1 at a composition of less than .60 per cent carbon. With an increase in carbon from .58 to 1.16 per cent the temperature positions of the transformations remain unchanged. Although the temperature of the maxima of the transformations and the range within which the transformations proceed are lowered by the increase in carbon the resulting positions, both on heating and cooling remain some 10 to 30 degrees Cent. above the ranges for the corresponding alloy-free, carbon steels. A comparison of steels B and C, of Fig. 2, with steel No. 1, of Fig. 1 illustrates the relative divergence.

CARBON GROUP HEATING AND COOLING CURVES

Fig. 1.—Shows the influence of carbon upon the thermal transformations of steel of a typical chromium-vanadium composition. Chemical composition.—Carbon, 0.16 per cent; chromium, 1.06 per cent; vanadium, 0.18 per cent.

Transformations Upon Cooling

Griffiths (4) reported results similar to those above on heating a carbon series of chrome-vanadium steels but further reported a considerable lowering of the transformations on cooling, roughly in proportion to the initial temperature from which the steel was cooled. Fig. 9 illustrates the 12 and 21 degrees Cent. lowering of Ar_1 and Ar_3 respectively with a 125 degree Cent. difference in initial temperatures. With greater amounts of carbon, the position of the Ar_{1-3} transformation is much less affected by changes in the initial temperature of heating. These relations hold for the cooling rates compared. Obviously a more rapid rate of cooling would produce a further lowering of the transformations.

The influence of carbon in overcoming the resistance introduced by the added elements, to the Ar_1 change is evident in a comparison of the amplitudes of this transformation. When the amount of carbon is appreciably increased as in steels No. 12 and 13, the solid solution, being more concentrated in carbon, promotes the precipitation and coalescence of the carbide. The uniformity in the temperature range within which the Ar_1 change occurred, suggested the preparation of Table II, to list the relative variations in the intensity of the Ar_1 change. A progressive increase in amplitude, allowing for the additive effect of Ar_3 in steels 12 and 13, with an increase in carbon, indicates the dominance of carbon in determining the position of this transformation in these steels.

The influence of the alloying elements upon the Ac_1 or carbide transformation is significantly expressed in the relative positions of Ac_1 and Ac_2 deflections. In the low carbon steels, Ac_2 occurs at a lower temperature than Ac_1. Its position in the curves was determined by its characteristic appearance, its magnitude and constancy of position in the critical ranges.

The occurrence of Ac_2 below Ac_1 had been reported by Moore (5) for chromium steels containing more than 3 per cent of that element, and by McWilliam and Barnes (6) for steels carrying 2 per cent chromium. In view of the low chromium content its unusual position in this series of steels is doubtless assisted by the influence of vanadium. The latter effect is more clearly shown in the vanadium group of steels.

The constancy in position and magnitude of the change to Beta iron both on heating and cooling marks the degree of independence of this transformation, of the A-1 change. Since the A-2 change is an allotropic one, not involving a change in phase, the physical properties, other than magnetic or electrical, are not appreciably altered.

The peculiar behavior of the A-2 change in the low carbon steels merits further consideration. Although the transformation appears to proceed, unhampered by the condition or constitution of the phases active in the critical range, there is little doubt but what the thermal disturbance is of sufficient intensity in many cases, to provoke the occurrence of a phase-change transformation which had been delayed by supercooling. The significance of the A-2 change in pointing toward changes in the constitution of some of these steels is mentioned in one of the subsequent paragraphs.

INFLUENCE OF UNUSUAL IMPURITIES INCLUDING VANADIUM UPON TRANSFORMATIONS

Fig. 2 is a comparison of the transformation curves of steels A, B, C and 2. The composition of these steels is shown on the chart.

Relation Between Transformations, Hardness and Structure

The relation between the transformations and the hardness of quenched specimens is illustrated in the curves of Fig. 3. Hardening in the low carbon steels is accomplished in two steps; one, corresponding to the solution of at least a portion of the carbides at Ac_1 and a second, corresponding to the further solution and dispersion of the dissolved elements, at Ac_3. The latter effect marking the end of Ac_3 is significant in the study of steels in which this transformation is feebly expressed in the thermal changes. Where the two transformations are combined, a marked increase in hardness accompanies their progress,

Table II

Intensity of Ar_1 Transformation

	——Composition——					Temp. Range of Ar_1	Amplitude in seconds	Sec.
No.	C	Cr	Vd	Rate	Ar_1 T.	Degrees Cent.	at Ar_1	.01% C.
A.....	.33	..	..	.13	709	699-715	78.5	2.38
B.....	.34	..	..	.14	680	670-690	82.3	2.42
11.....	.16	1.03	.20	.13	694	682-700	52.8	3.30
1.....	.30	.93	.18	.13	697	685-703	85.9	2.87
12.....	.58	.73	.18	.12	690	682-703	148.1	2.60
13.....	1.16	1.06	.20	.11	692	676-700	174.3	1.50

as shown in the curve for steel No. 13. An increase in hardness in specimens quenched at temperatures, increasing progressively, above Ac_3 apparently marks the distribution of carbon in the iron-chromium solvent; the more thorough dispersion produced by the higher temperatures.

The structures of the carbon group of steels generally resembles those of the corresponding alloy-free, carbon steels. A brief description has been given in an earlier presentation (20).

Thermal Transformations in the Vanadium Group

Transformations Upon Heating

The thermal effects produced by varying the vanadium content of a chrome-vanadium steel, are shown in Fig. 4 and recorded in Table III. An examination of the curves shows that the changes in the positions of the transformations, in the composition range investigated, are small. If a comparison be made between curves B and C of Fig. 2 with curve 2 of the same figure, a slight rise in the position of Ac_1 is evident. This change may be attributed to the presence of vanadium, although a correction for the influence of silicon and manganese in respectively raising and lowering this transformation, must be considered.

The vanadium addition, probably in the form of a complex carbide, is effective in retarding the Ac_3 transformation, such that the heat absorption accompanying the solution of the element in the gamma iron solvent, is difficult to locate in the thermal curves. A portion of the heat absorption is contained in Ac_1, but a greater portion seems to be

Table III

Thermal Data

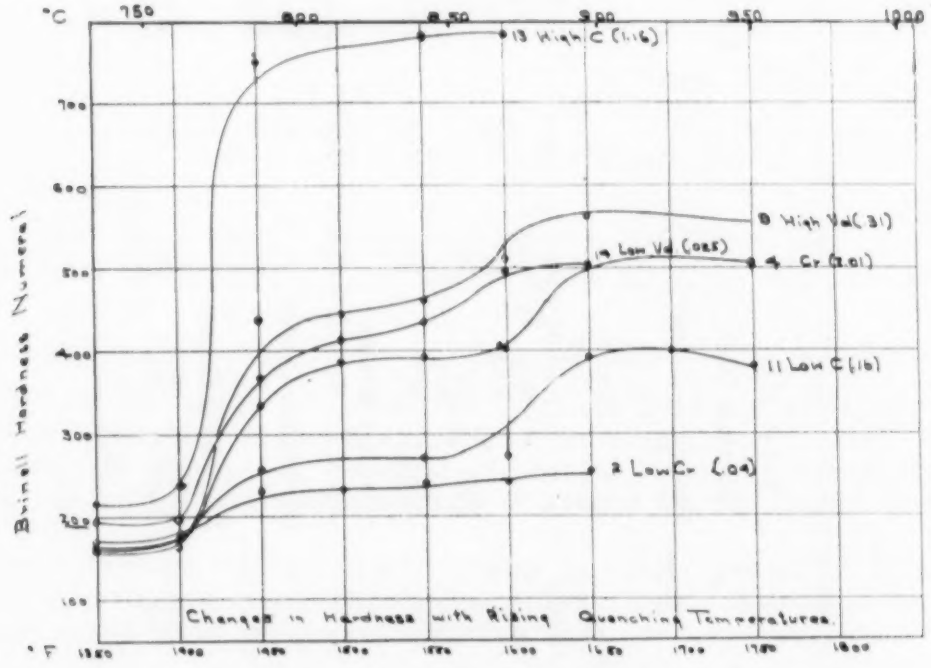
Vanadium Group

No.	Composition C	Cr	V	Ac-1	Ac-2	Ac-3	Temp. Degrees Cent. (Initial)	Ar-3	Ar-2	Ar-1	Ratio Cr:C	Ratio Cr+V:C	Amplitude Ar_1
14	.40	1.05	.025	758	...	...	975	706	...	694	2.6	2.7	128
7	.37	1.05	.07	762	...	...	975	711	706	696	2.8	3.0	139
1	.30	.93	.18	768	764	807	975	747	...	697	3.1	3.4	86
9	.37	1.07	.31	772	766	...	975	717	...	696	2.9	3.7	113
10	.27	1.24	.65	781	768	834	975	786	768	713	5.2	7.6	55
							Carbon Group						
11	.16	1.03	.20	776	766	827	975	783	766	694	6.6	7.8	53
							Chromium Group						
2	.38	.04	.19	747	...	...	975	745	...	684	..	..	120
							Alloy-Free Group						
B	.40	...	..	733	765	784	975	724	...	676	..	..	78
C	.34	...	...	734	764	797	975	750	...	680	..	..	82

concealed in the faint, but continued heat absorption above Ac_1.

The position of Ac_2 with increasing vanadium is inverted when 0.18 per cent of the element has been added. The transformation retains it's temperature position with the addition of vanadium. The separation of Ac_2 from Ac_1 is caused as previously mentioned, by the progressive resistance to solution of the complex carbides which form, and the constancy of the change from alpha to beta iron irrespectively of the influence of the small amount of added elements.

That the thermal disturbance at A-2 is active in precipitating the Ac_1 transformation is apparent from the curves for steels 1, 9 and 10. In steels 1 and 9, Ac_2 had occurred within the Ac_1 transformation range, as indicated by the sudden heat absorption. In steel 10 the sharp heat



CHANGES IN HARDNESS WITH RISING QUENCHING TEMPERATURES

Fig. 3.—The hardness of the high and low vanadium steel are shown in the above curve. A study of the curve shows that sharp increases in hardness is obtained in passing Ac_1 followed by a second increase at higher temperatures.

absorption at Ac_2, was sufficient to precipitate the Ac_1 change which existed in a slightly super-heated state at the temperature of Ac_2. When the amount of alloying elements is sufficiently large, A-2 occurs independently of the remaining transformations due to its lowering and an attendant raising of Ac_1.

Transformations Upon Cooling

In cooling, the upper transformation appears to be slightly raised, but the movement with changes in composition, is more directly related to the variations in the carbon content or the chromium to carbon ratio, which is determined by the carbon content. This effect is revealed in a comparison of the position of the transformations in steel 11 of the carbon group, with steel 10 of the vanadium group. The 0.08 per cent increase in carbon in the latter, is nearly sufficient to balance the influence of the 0.58 per cent vanadium addition.

The level of the Ar_1 transformations remains some 15 to 20 degrees

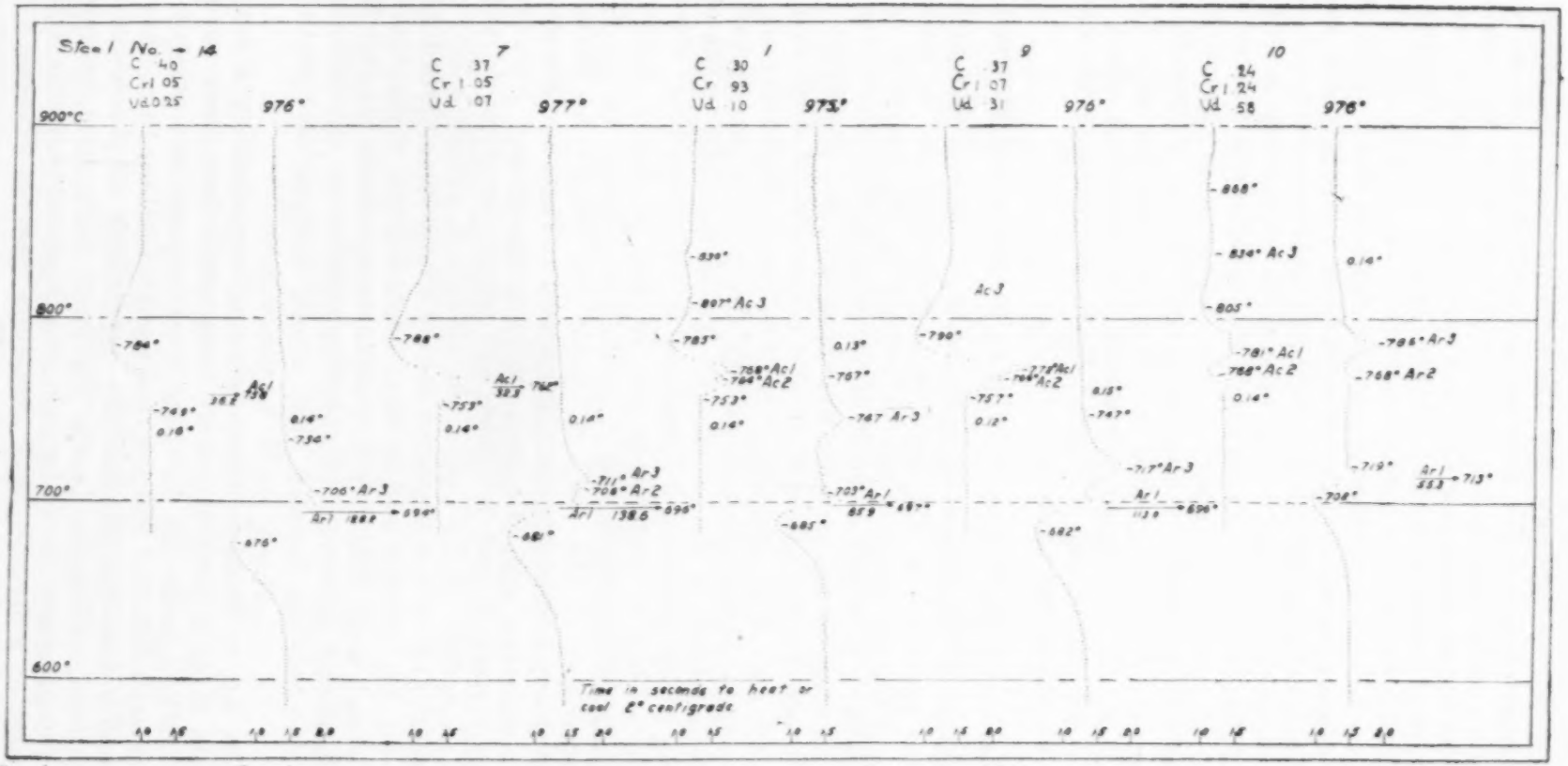
Cent. above the corresponding level for equivalent alloy-free carbon steels, and rises rather abruptly for the 0.65 per cent vanadium steel. This slight departure from the normal position of this transformation agrees with the results obtained by Pultz (7) and later by Norris (8), which show a 10 degree Cent. rise for a 0.20 per cent addition of vanadium to a plain carbon steel. Pultz further reports that "additions of vanadium up to 0.98 per cent have no effect upon Ar_1 but Ar_{3-2} is raised in proportion to the amount of vanadium added." The 0.5 degree Cent. rise for each 0.01 per cent vanadium appears to be repeated in the Ac_1 transformation for these chrome-vanadium steels. If, for example, steel 14 (Fig. 4) containing very little vanadium is compared to the curve of steel 2 (Fig. 2) a slight rise in the position of Ac_1 is evident, which is apparently caused by the difference in chromium. An examination of the positions of the Ac_1 points in the vanadium group, shows an increase of approximately 0.5 degrees Cent. for each 0.01 per cent of vanadium. This change represents the combined effect of the variations in composition and a slight allowance needs to be made for difference in chromium and carbon.

Significance of Changes and Relation to Hardness and Structure

The tendency of vanadium to combine with the carbide formed in steels, has been reported in the work of Arnold (9) and is quite generally known. This tendency is not prevented by the presence of chromium. Apparently a complex carbide of iron-chromium occurs, due to the replaceability of iron in the carbide by vanadium and chromium. This effect would be thermally indicated in the distortion or displacement of the transformations. The amplitude of the Ar_1 transformation which marks the intensity of the change during the carbide precipitation remains quite proportional to the amount of carbon involved in the change, thus expressing the dominating influence of this element upon the course of the change. This is further shown in the unaltered temperature position of the transformation, for a vanadium content up to 0.30 per cent. A comparison of the data in Table III shows an increase in temperature and amplitude for the alloy steels. The changes in amplitude are not consistent with the changes in composition. For example, a comparison of steels 7 and 9, which are nearly identical in composition with the exception of the vanadium difference, shows a decrease in intensity of Ar_1. This is compensated for by the greater spread between the beginning of Ar_3 and the end of Ar_1, indicating the separation of the compounds through a considerably increased temperature range. No evidence of a slackening of arrest in the displacement or distortion of the transformations could be located that would suggest a constitutional change.

The rise in Ac_1 with an increase in vanadium showing a resistance to the solution of this element or its compounds has been mentioned above. Apparently a complete solution, for the quantities present, is accomplished between 850 and 900 degrees Cent. Cooling from these temperatures and 975, does not produce an appreciable displacement of the Ar transformations. Changes in the hardness of specimens quenched from various temperatures over the critical range, support this view.

The hardness of a high and low vanadium steel, as presented in Fig. 3, shows a sharp increase in passing Ac_1 followed by a second increase at



VANADIUM GROUP HEATING AND COOLING CURVES

Fig. 4 shows the thermal effects produced by varying the vanadium content of a chromium-vanadium steel. An examination of the carbon shows that the changes in the position of the transformations in the composition range investigated are small. The composition of each steel is recorded on the chart.

higher temperatures. A partial dissociation of the carbides at the lower temperature, is evident. Although the Ac_3 transformation appears but feebly in the thermal curves, its position is quite decisively located in the hardness curves. The increase in hardness produced by quenching from temperatures above Ac_3 is doubtless due to the progressive dispersion of the dissolved elements. Structures of quenched specimens are martensitic, and no evidence of a free constituent is detectable.

The structures, in general, resemble those of the corresponding carbon steels. The concentration of vanadium in the carbide of annealed specimens, is amply illustrated by comparing Figs. 5 and 5a, the latter showing the carbide constituent collected into a thin network of globules.

Thermal Transformations in the Chromium Group

The chromium group of steels might well be separated into two divisions, one comprising small increments, to a total of 2 per cent of the added element and a second division comprising large increments, as represented by the 7, 14, and 21 per cent chromium steels. The narrow range of carbon contents, the disturbing effects of vanadium and the usual impurities, prevent the direct application of some of the results, to the amplification of the chromium-carbon system.

However, the dominating influence of the chromium on the properties of the steels makes a description and discussion of the thermal transformation on the basis of the present state of the ternary iron-carbon-chromium system, desirable.

Recent work by Edwards (10)-(11)-(12), Murakami (13), Monypenny (14) Daeves (15), Russell (16), and others has added many facts to our knowledge of the constitution of the iron-carbon chromium system and the peculiar behavior of its alloys under various thermal treatments. However, the unstable position of our knowledge of the chromium alloys emphasizes the need for additional facts which may be used in charting the influence of this important element.

The early work of Osmond* indicated important changes in the behavior of the thermal transformations with the addition of chromium, as for example, the raising the Ac_1 points with an increase in chromium.

Transformation Upon Heating

The influence of chromium on the transformations upon heating is shown in the curves of Fig. 6.

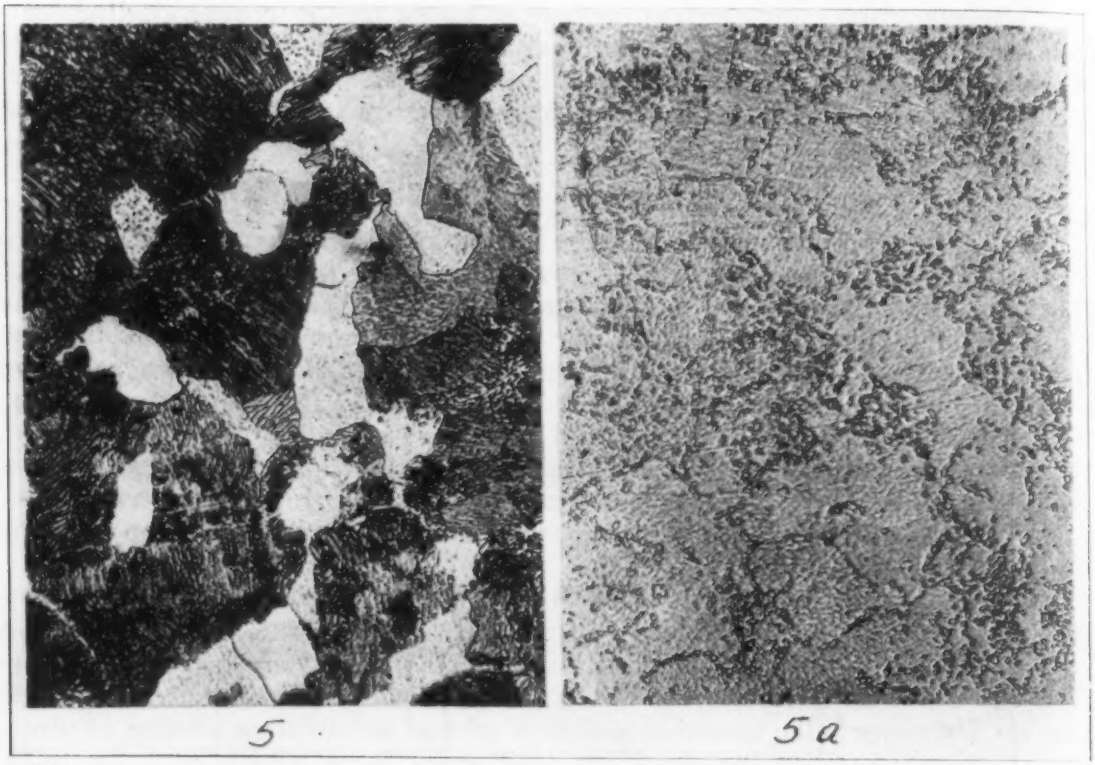
As previously mentioned, the addition of chromium to a carbon-vanadium steel, raises the critical points to a degree suggesting the cumulative action of the two alloying elements. A gradual rise in Ac_1 marking the solution of a portion of the carbides, is evident. When the quantity of chromium exceeds two per cent, the rise becomes more pronounced as shown in curve No. 5, but the rate of increase is not sustained with a further addition of chromium.

At a position representing a concentration of ¾ per cent chromium, as interpreted from Fig. 8, Ac_2, which remains comparatively fixed on heating and cooling, is joined by Ac_1 to form a single inflection. Obviously, a change in composition would slightly shift the junction of the two transformations. The lowering of the Ac_1 range with a slight increase

*Ibid.

in carbon and the effect of greater amounts of chromium in lowering the A-2 transformation would be expected. Up to this point, chromium appears to enter chiefly into the carbide, as marked by the Ac_1 rise, leaving little evidence of an iron-chromium solution.

An indication of the iron-chromium solution is found in the marked lowering of the A-2 change. The rate of lowering with an increasing



MICROSTRUCTURES

Fig. 5.—Photomicrograph of an annealed low vanadium steel (0.025 vanadium) x 500. Fig. 5a.—Photomicrograph of an annealed vanadium steel (0.58 vanadium) showing the carbide constituent collected in the fine network of globules x 500.

chromium content, is more rapid than that reported by Murakami* for the change in position of A-2 with additions of chromium to iron, thereby suggesting that the remaining impurities, notably silicon and vanadium exert a similar influence upon the depression of the transformation. Since A-2 is not accompanied by a phase change its behavior in the thermal curves might be disregarded. However, the intimate relation between the A-2 change and the alpha to gamma change, make the former extremely helpful in indicating changes in the latter.

If, for example, the vanadium content be ignored, most of the chromium up to 7.7 per cent appears to enter principally into the carbide as indicated in the impedance of the carbide solution and alpha to gamma change. The temperature for Ac_1 rises to 819 degrees Cent. which is roughly 100 degrees Cent. above the corresponding change in an alloy-free carbon steel, while the Ac_2 change which effectively marks

*Apart from the characteristic appearance and small thermal disturbance produced, the identity of the A-2 change was verified by repeated heating to temperatures slightly above the Ac_2 position. In each case the reverse transformation occurred in cooling at a temperature within a degree or two of that observed in heating, thus revealing the reversibility which is characteristic of this particular change.

the influence of chromium on the iron, is lowered about 5 degrees Cent. by the same amount of the element. A further increase in chromium to 14.4 per cent (as in specimen 6) raises Ac_1-$_3$ but slightly, while A-2 is appreciably lowered. This phenomenon immediately suggests the formation of a limiting compound of carbon and chromium near the 7.7 per cent composition and the release of the surplus chromium into the iron to form an iron-chromium solution. The rise in Ac_1 is due, no doubt, to the retarded solution of chromium-iron carbides but in arriving at 7.7 per cent chromium the slight lowering of Ac_2 below the carbide solution temperature indicates the presence of an iron-chromium solution in which chromium is lowering the temperature of the alpha to gamma conversion. The 20:1 chromium to carbon ratio which is represented by this composition closely agrees with the formula (Fe_3C: Cr_4C) for the gamma carbide proposed by Murakami*. The presence of this compound would account for the high position of Ac_1

The composition of the carbides which appear in chromium steels is disputable, and an estimate made from these few alloys would be hazardous. It appears quite certain that a transition from Fe_3C to some carbide such as Cr_4C or Cr_5C_2, occurs in which chromium gradually replaces iron when equilibrium conditions have obtained. Edwards and Norbury (12), by means of resistance measurements, have found strong indications of a double carbide corresponding to the formula Fe_3C-Cr_3C_2 and suggested that chromium up to a ratio of 4.3 to 1 is combined with carbon to form this carbide. While this composition ratio seems to hold for the 1 per cent carbon steels, it appears from this series of steels that a variation upward, with an increase in chromium and downward with an increase in carbon takes place. The peculiar behavior of the iron-chromium system, from the data available, suggests a constitutional change in the ternary diagram, (for steels containing less than 15 per cent chromium) along a smooth line corresponding to the Acm or S E line of the binary, iron-carbon diagram. Data presented by Monypenny* and Daeves*, support this view. Interruptions in this line, corresponding to the formation of distinctive carbides, in the range between it and Ac_1, are, however, quite probable. In fact, the degree of resistance to etching of the carbide particles increases as the chromium to carbon ratio increases. An etching test has been used by Murakami to classify some of the carbides he proposes. Similar experiments, repeated on the chromium group of steels listed above, have not yielded convincing results.

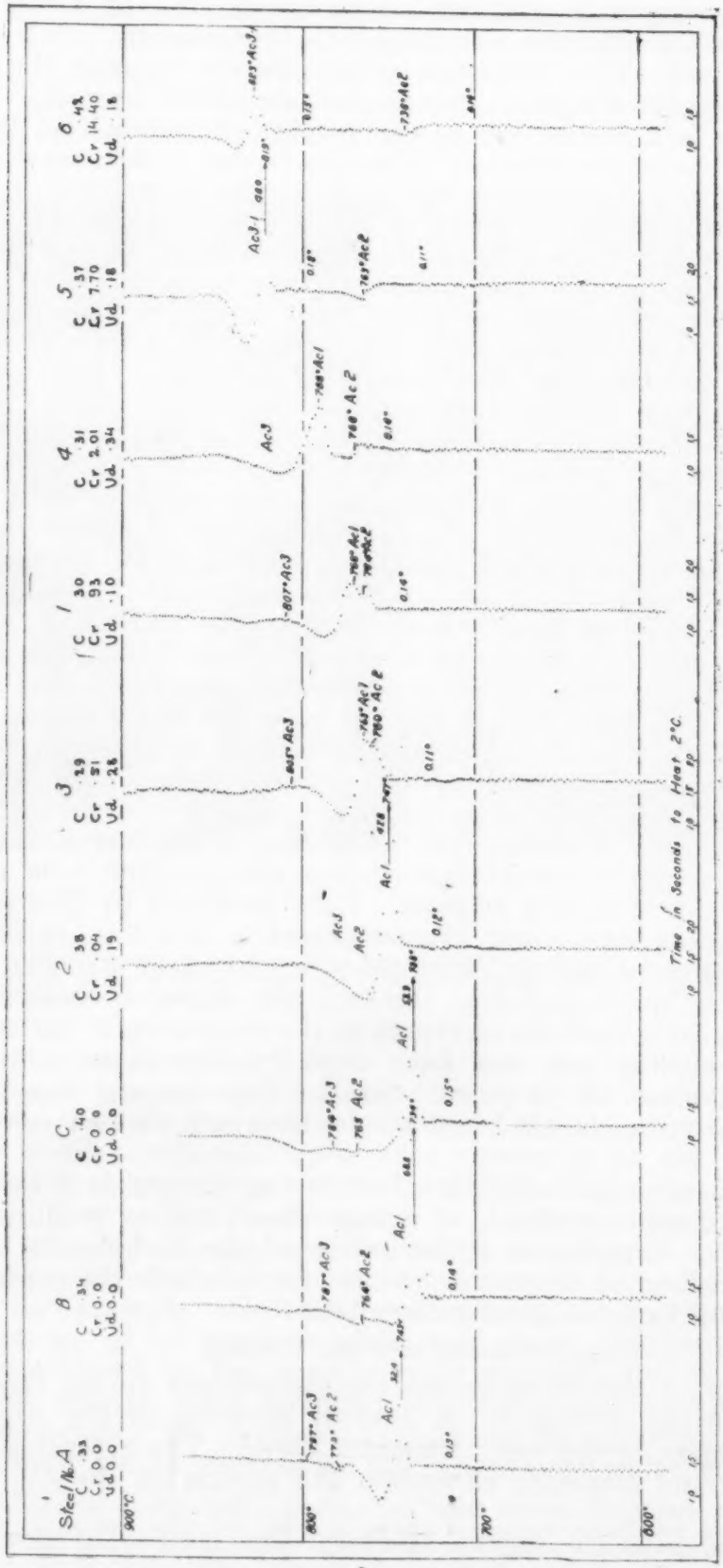
Since the quantity of carbide involved in the changes in these steels, is small, direct thermal evidence of a heat absorption or evolution corresponding to the dissociation or formation of the carbides is lacking. Evidence of the effect of chromium on the rate at which the transformations proceed, will be subsequently described.

Transformations During Cooling

The influence of chromium on the transformations during cooling, is shown in the curves of Fig. 7. A gradual lowering of the Ar_3 transformation is evident in the low chromium range. The retarding action of the dissolved and dispersed chromium and carbon on the Ar_3 change is apparent.

The Ar_1 change is but slightly affected. The position of this change

*Ibid.



CHROMIUM GROUP Ac THERMAL TRANSFORMATIONS

Fig. 6 shows the influence of chromium upon the transformations upon heating. It will be noted that the addition of chromium to a carbon-vanadium steel raises the critical points to the degree suggesting the cumulative action of the two alloying elements.

is graphically presented in Fig. 8. The increased stability of the chromium carbides appears in the gradual rise in Ac_1, which, if projected, meets Ac_3 at a point approximating a composition of 3.1 per cent chromium. The projection of the position of the Ar points results in an intersection at 2.65 per cent chromium. The field between which the A-1 and A-3 points combine, apparently represents a region which covers a critical point in the constitution and treatment of the steel. For the hypothetical zero rate of heating and cooling, the intersection would probably occur at about 3 per cent chromium, which would result in a chromium to carbon ratio closely corresponding to the 10:1 ratio tentatively proposed by Edwards* for the corresponding carbide, Cr_5C_2. For steels containing .30 to .40 per cent of carbon, this intersection marks the maximum amount of chromium and carbon that may be dissolved and completely reprecipitated when the cooling rate and initial temperature designated, are a maximum. Exceeding this initial temperature, rate of cooling or chromium content produces a super cooling which results in the unstable (hardened) state, indicated by the split transformation.

An increase in chromium from 2.0 to 7.7 per cent produces an increased resistance to the normal transformations. As shown in the curves for steels 5 and 6 (Fig 7), the lowered or split transformation is obtained with this chromium increase. A further increase in chromium to 21 per cent reveals a faint, reversible, thermal disturbance, corresponding to the A-2 transformation and a feeble evolution of heat in the 350-170 degree Cent. range upon cooling, corresponding to the Ar" transformation.

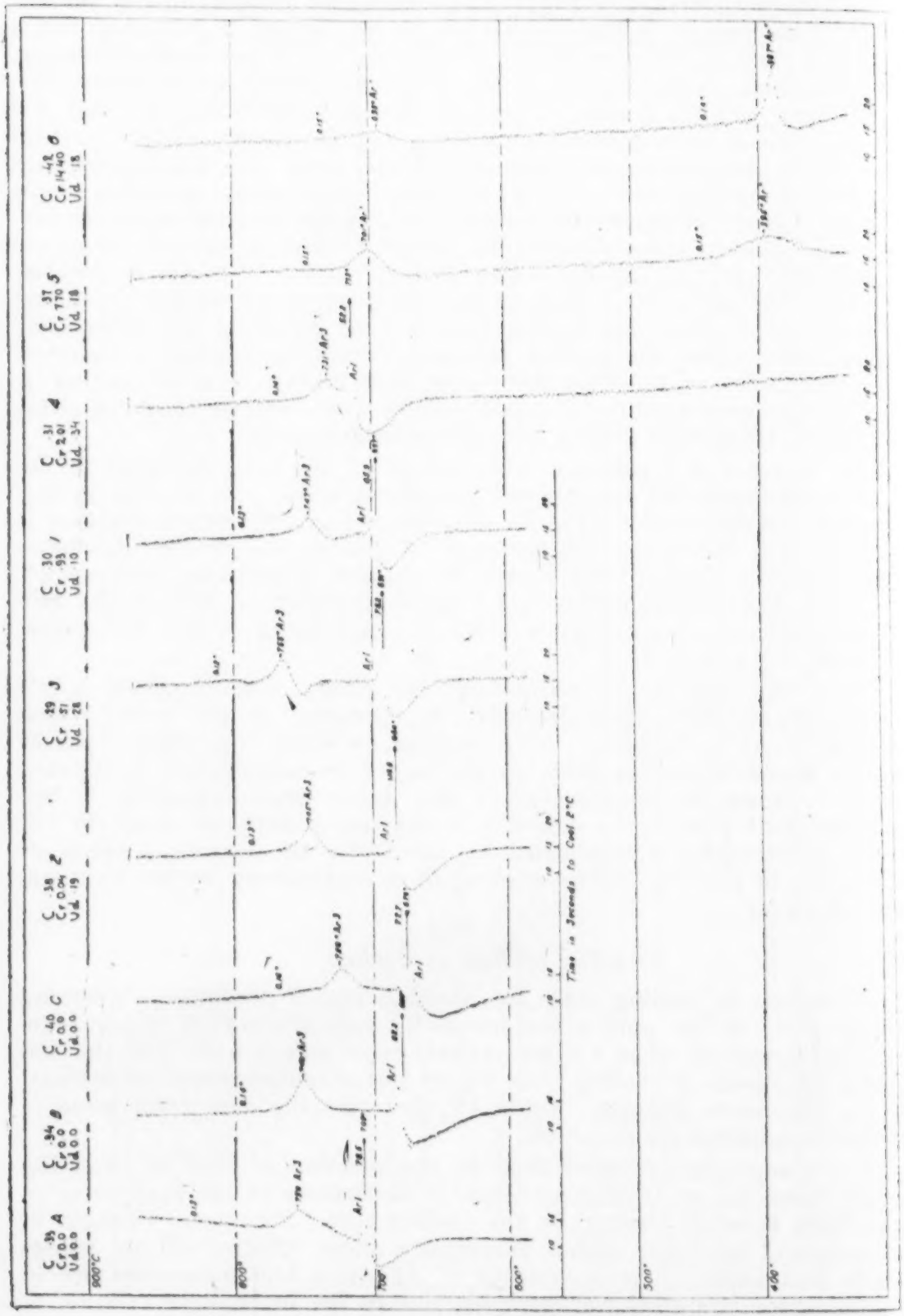
With the addition of chromium, the upper transformation (Ar') is gradually lowered then decreased in intensity as the lower transformation (Ar") becomes more intense, whence the latter passes through a maximum intensity as the upper transformation disappears. Finally a complete suppression of the lower transformation, is approached. This shift in the intensity of the transformations, with the addition of chromium is duplicated by increasing the rate of cooling, or approached in performance by cooling from successively higher temperatures above Ac_1.

Effect of Rate of Cooling

A change in cooling rates for steels 5 and 6 produces a lowering of both parts of the split transformation, with a complete suppression of the upper portion when a comparatively rapid rate is used. The thermal effect is analogous to cooling from higher initial temperatures, or increasing the chromium content. Table IV abstracts the data from some of the curves which were obtained.

The comparatively rapid drop in the position of Ar" in changing the rate from .12 to .16 degrees Cent. is illustrative of the sensitivity of these steels to small changes in the cooling rate. Significant changes in structure and hardness which accompany these effects will be subsequently mentioned. The occurrence of Ar" at a higher temperature in the high chromium steel was probably due to the incomplete solution of the carbides at the temperature from which cooling began; namely 977 degrees Cent.

*Ibid.



CHROMIUM CARBON Ar THERMAL TRANSFORMATIONS

Fig. 7.—This curve shows the influence of chromium on thermal transformations of several steels during cooling. A greater lowering of the Ar_3 transformation is evident in the low chromium range. A retarding action of the dissolved and dispersed chromium and carbon on the Ar_3 range is apparent. The compositions of the steels are shown on the chart.

Effect of Initial Temperature of Cooling

The effect of cooling from different initial temperatures upon the position of the transformation is shown in Figs. 9 to 13, inclusive. The results have been collected in Fig. 14.

In the low chromium steels, both Ar_3 and Ar_1 are lowered, when cooling is begun from successively higher temperatures. Of the two, Ar_3, is more rapidly displaced.

In the curves for steels 5 and 6, Ar″ is not directly detected in cooling from 850 and 900 degrees Cent. A lowering of the upper transformations and a decrease in their intensity implies their partial suppression and leads to the expectation of the occurrence of the suppressed portion in a lower inflection. Cooling from 975 and 1025 degrees Cent. produces a greater displacement upon cooling from the higher initial temperature.

Table IV

Effect of Rapid Cooling

Steel No.	Per Cent. Cr.	Rate—Degrees Cent. per sec.	Ar′	Ar″
5	7.7	.12	703	394
5	do	.15	701	395
5	do	.16	693	351
5	do	.88	none	320
6	14.4	.15	681	363
6	do	1.10	none	337

In steels of this type, the split transformation observed with increasing initial temperatures has been regarded as being caused by the obstruction to the normal transformations, introduced by the dissociation of the carbides. Where the chromium to carbon ratio is very high, a generalization of the hypothesis proposed by Murakami; namely, that the "lowering of the transformations is produced by the dissociation of the carbides and the retarding action of free chromium," appears to most satisfactorily fit the available data. In view of the two sources of free chromium, namely that present in the iron-chromium solvent and that derived from the carbide solute, two views might be advanced to account for the high initial temperatures required; namely the resistance to dissociation of the chromium-carbide particle or the resistance to diffusion of the elements of the carbides in the iron-chromium solution. Until the composition of solute and solvent are better established, it seems best that the retarding action of free chromium irrespective of its source be emphasized as the predominating cause of the displaced or split transformations.

Convincing evidence of the specific composition of the carbides, is lacking, but the results in general agree in showing that a progressive solution of the carbides occurs as higher temperatures are used. Quenched specimens of steels which show the split transformation, reveal a perceptible decrease in the number or size of excess carbide particles, with increasing quenching temperatures.

For example, in steel No. 5, cooling from 850 and 900 degrees Cent. produced a slight lowering in the single, observed, transformation. An examination of the structure and hardness indicates a progressive solu-

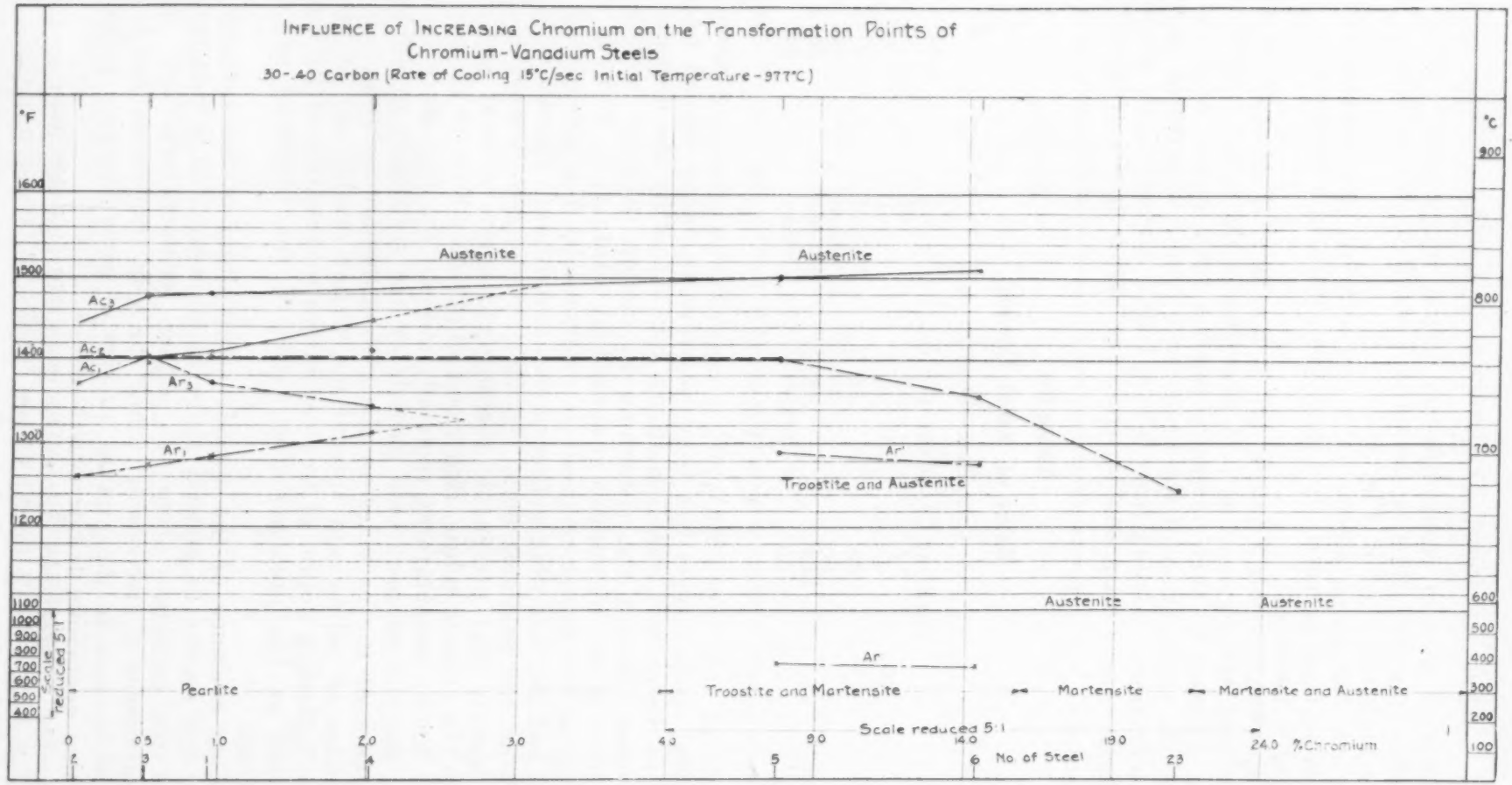
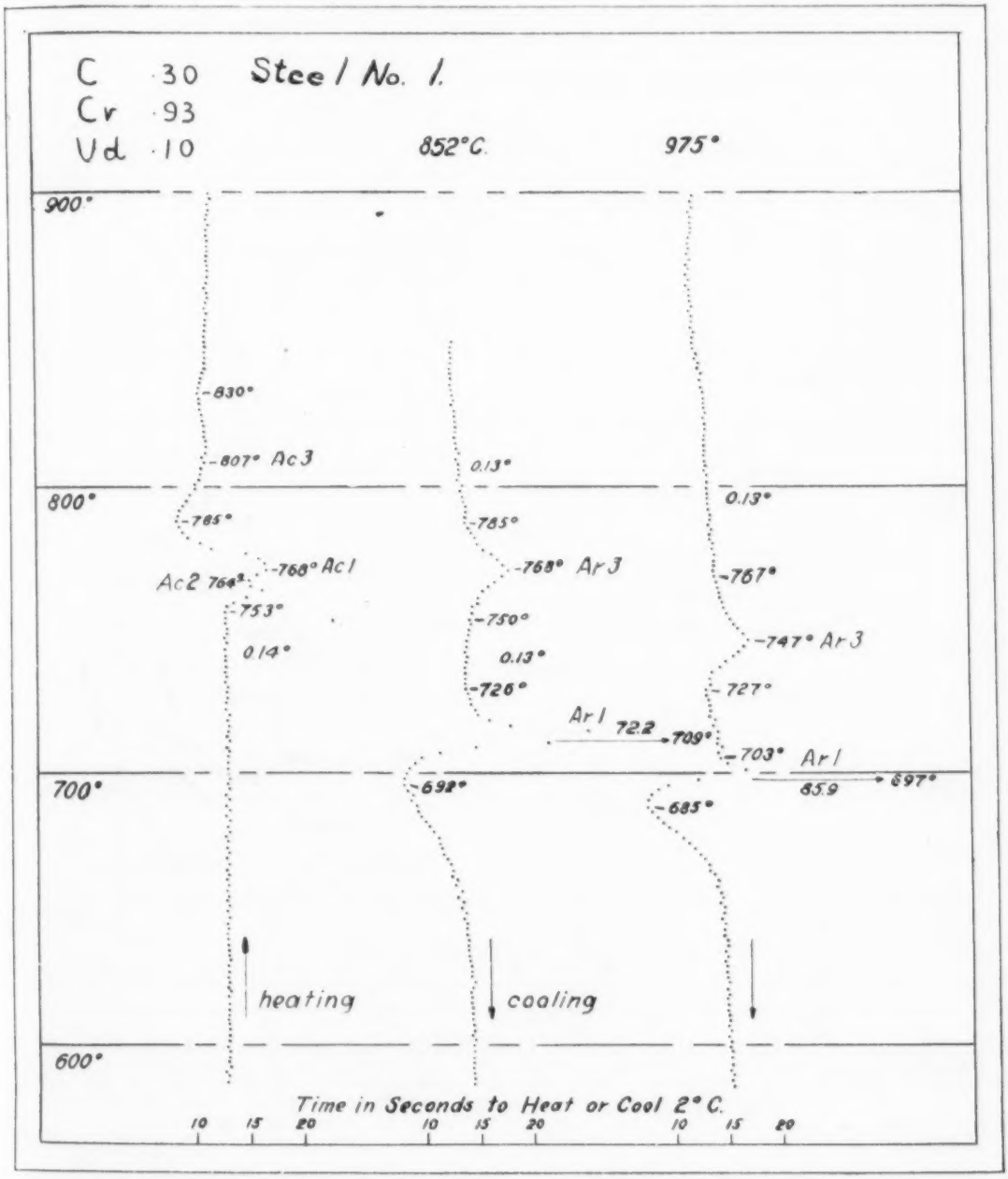


Fig. 8.—It will be noted that at the position representing the concentration of 0.75 per cent chromium the Ac_2 point which remains comparatively fixed on heating and cooling is joined by Ac_1 to form a single inflection. A change in composition would slightly shift the junction of the two transformations. Lowering the Ac_1 range with a slight increase in carbon and the effect of greater amounts of chromium in lowering the A-2 would be the result. The chromium appears to enter apparently in the carbide as marked by the Ac_1 rise leaving little evidence of the iron-chromium solution.

tion of the free carbides. Microscopically, the carbides in this steel disappear when a quenching temperature of 950 degrees Cent. is used. A cooling curve, from 977 degrees Cent. shows the split transformation

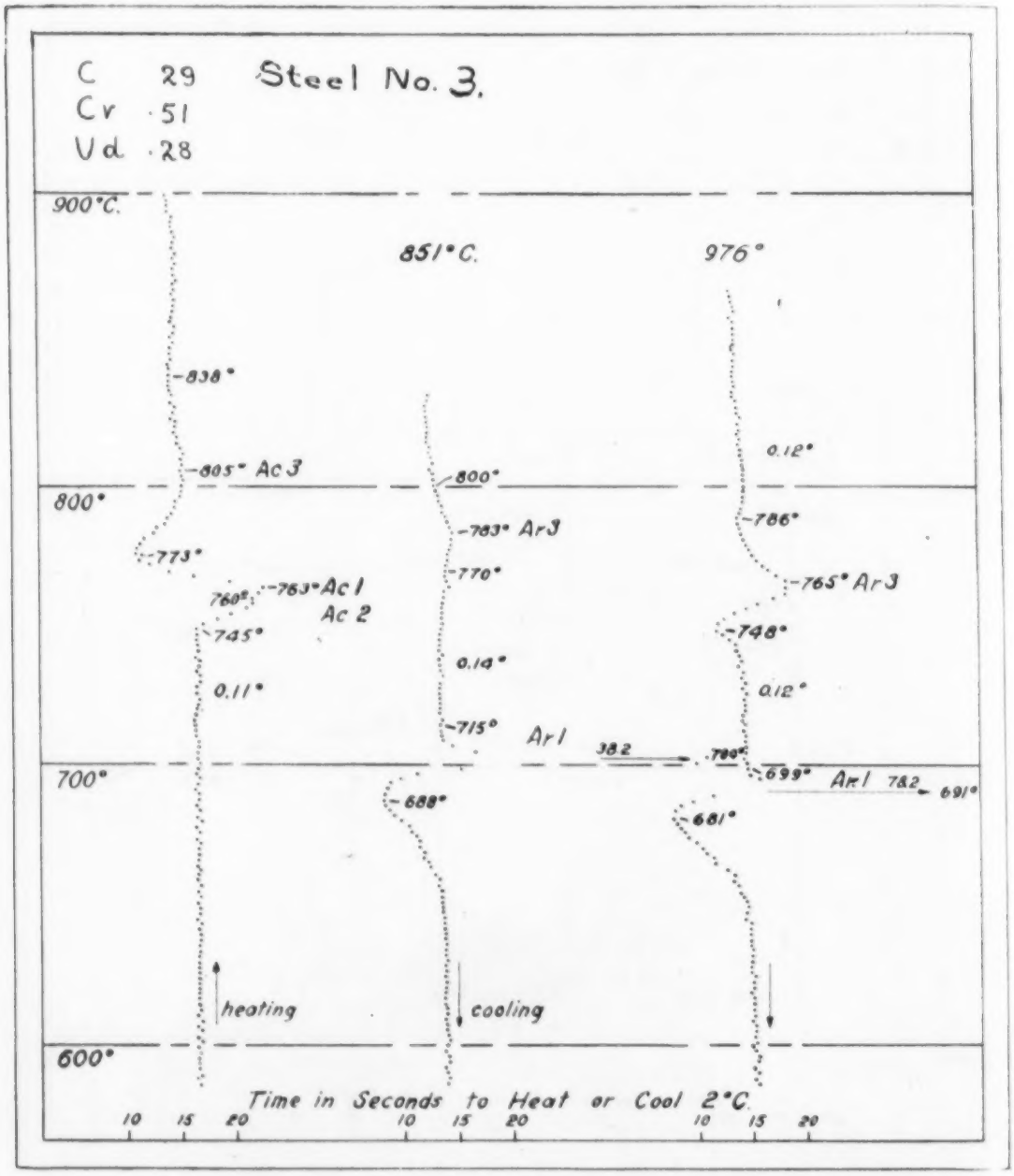


THE EFFECT OF HIGHER INITIAL TEMPERATURES

Fig. 9 shows the effect of higher initial temperatures upon the thermal-critical points both on heating and on cooling of the chromium-vanadium steel No. 1, which has the following composition: Carbon, 0.30 per cent; chromium, 0.93 per cent; vanadium, 0.10 per cent.

which might be associated with the disappearance of the carbides, except that cooling from a higher temperature produces an additional lowering. Changes in the intensities of the transformations are evident; the upper decreasing while the lower increases. This effect, increasing with rising initial temperatures, is apparently produced by the progressive dispension of chromium and carbon in the austenitic solution. Indeed the relation be-

tween the increased solubility and the distribution of the particles of the dispersion indicate a progressive course of division of the undissociated particles similar to the dispersion of $Cu\text{-}Al_2$, described by Jeffries (17)

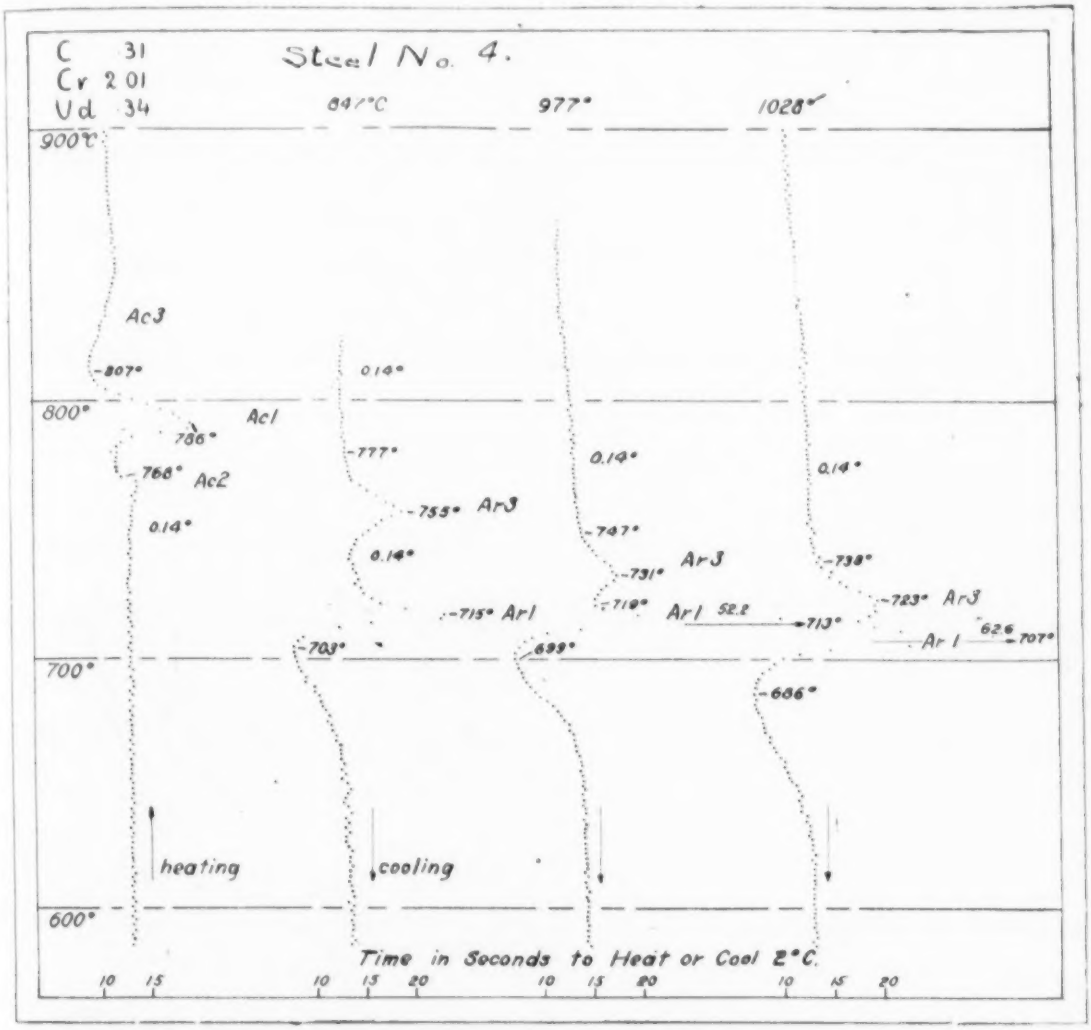


THE EFFECT OF HIGHER INITIAL TEMPERATURES

Fig. 10 shows the effect of higher initial temperatures upon the thermal-critical points both on heating and on cooling of the chromium-vanadium steel No. 3 which has the following composition: Carbon, 0.29 per cent; chromium, 0.51 per cent; vanadium, 0.28 per cent.

in copper-aluminum alloys. In view of the microscopically complete solution, existing at 950 degrees Cent. and the lack of any evidence indicating the presence of a carbide in molecular form, it seems certain that the state of division passes physically and chemically into submicroscopic and sub-molecular dimensions respectively. A maximum degree of dispersion would be approached when a temperature above 950 degrees

Cent. or prolonged heating at 950 degrees Cent. produced no appreciable change in the temperature position or magnitude of the transformations. This condition would correspond to a perfect solution or one in which the atoms of the solid solute and solvent were homogeneously distributed. In such a solid solution, the carbon atom which is most important in

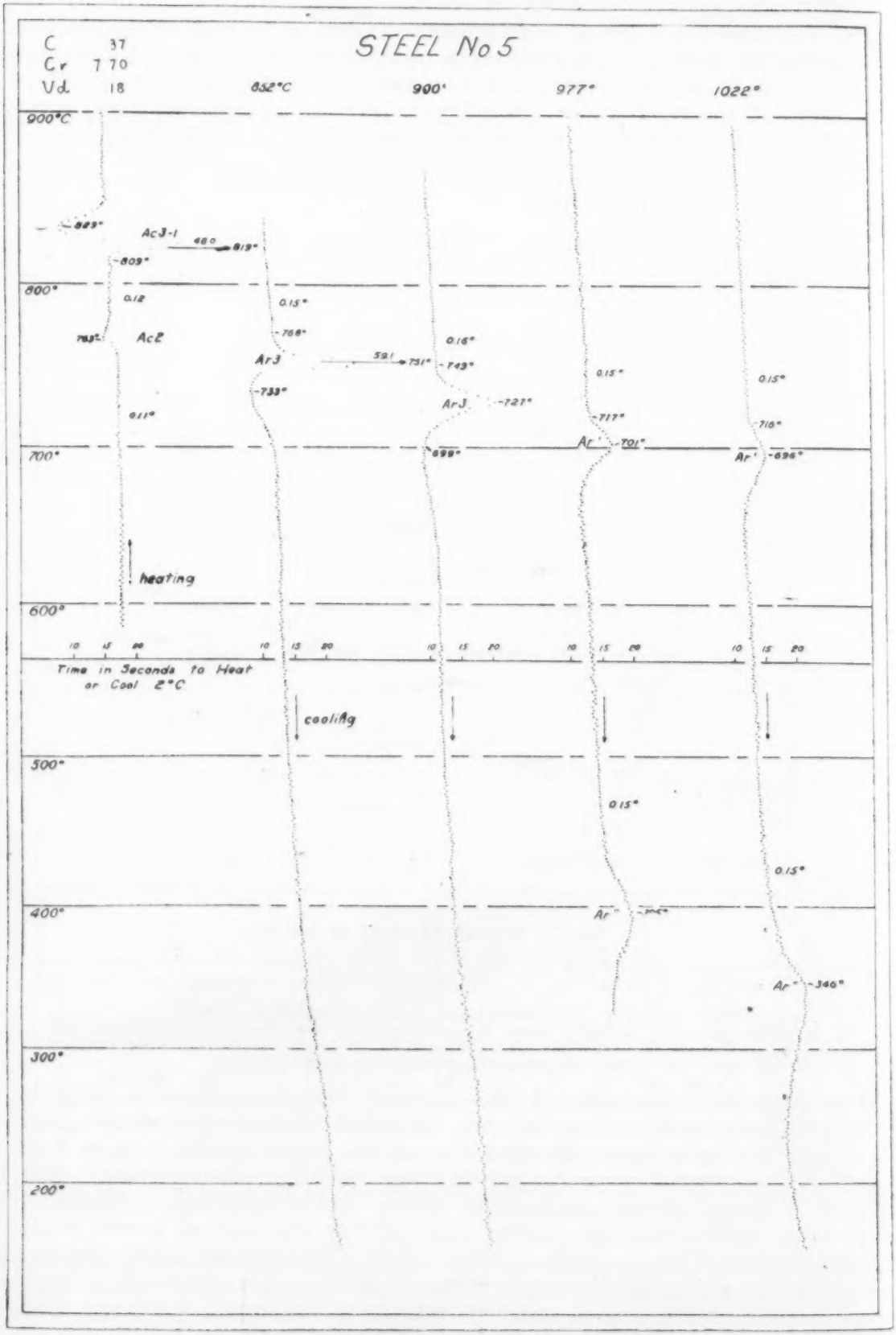


THE EFFECT OF HIGHER INITIAL TEMPERATURES

Fig. 11 shows the effect of higher initial temperatures upon the thermal-critical points, both on heating and on cooling of the chromium-vanadium steel No. 4 which has the following compcsition: Carbon, 0.31 per cent; chromium, 2.01 per cent; vanadium, 0.34 per cent.

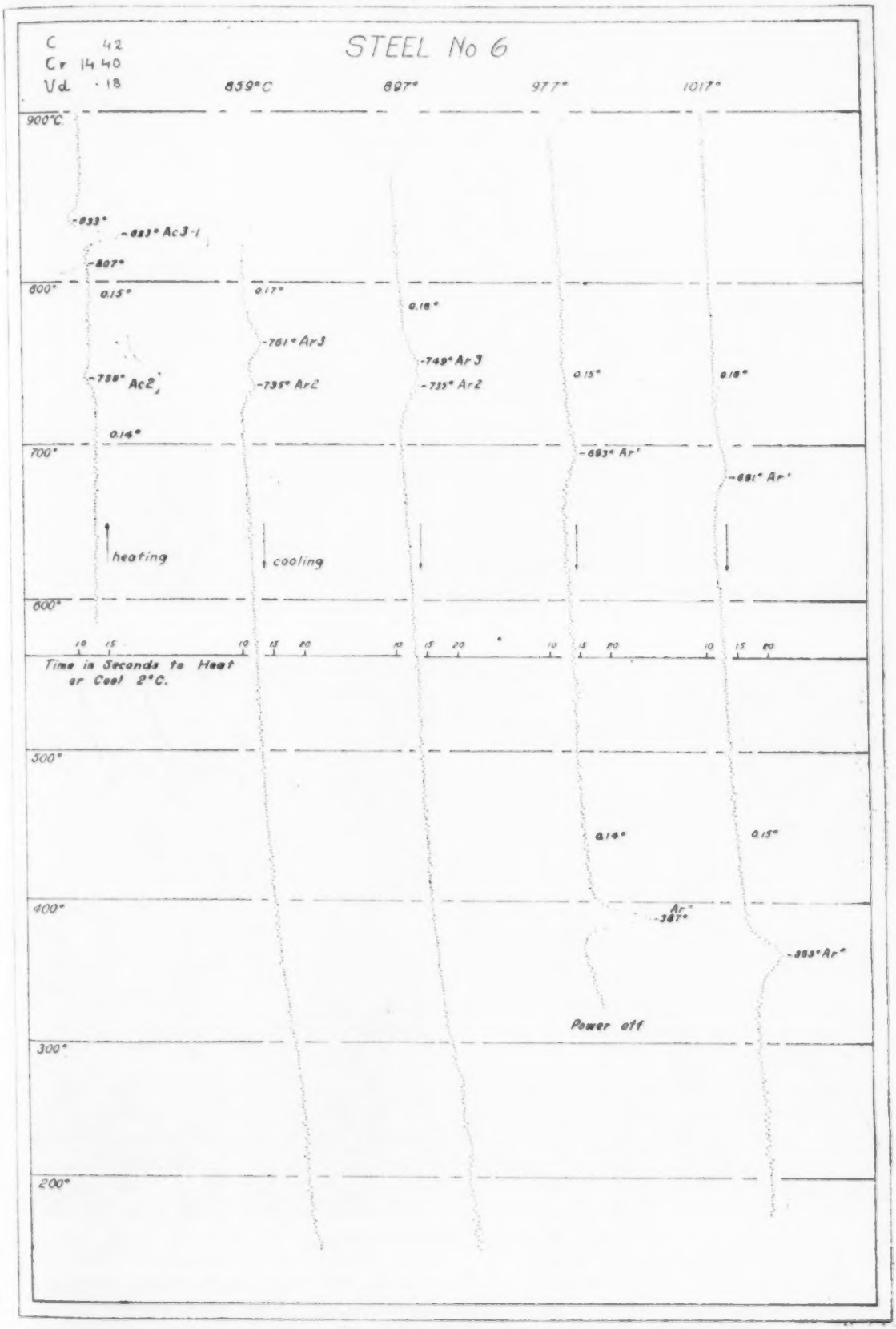
determining the character of the thermal transformations, would be lodged in an iron-chromium solvent. A small number of carbon atoms, as designated by a high chromium to carbon ratio, would require high initial temperatures or prolonged heating for their distribution. Conversely, a large number of carbon atoms would facilitate solution in heating or coalescence in cooling, and permit the use of lower initial temperatures and more rapid cooling rates. Throughout these changes, chromium in a highly dispersed form, or in solution, prevents a rapid reassociation of the compounds by retarding the rate of change from one form to the other.

The resistance of chromium to diffusion in iron, is well known. The difficulty in producing a homogeneous, chromium-iron solution, and



THE EFFECT OF HIGHER INITIAL TEMPERATURES

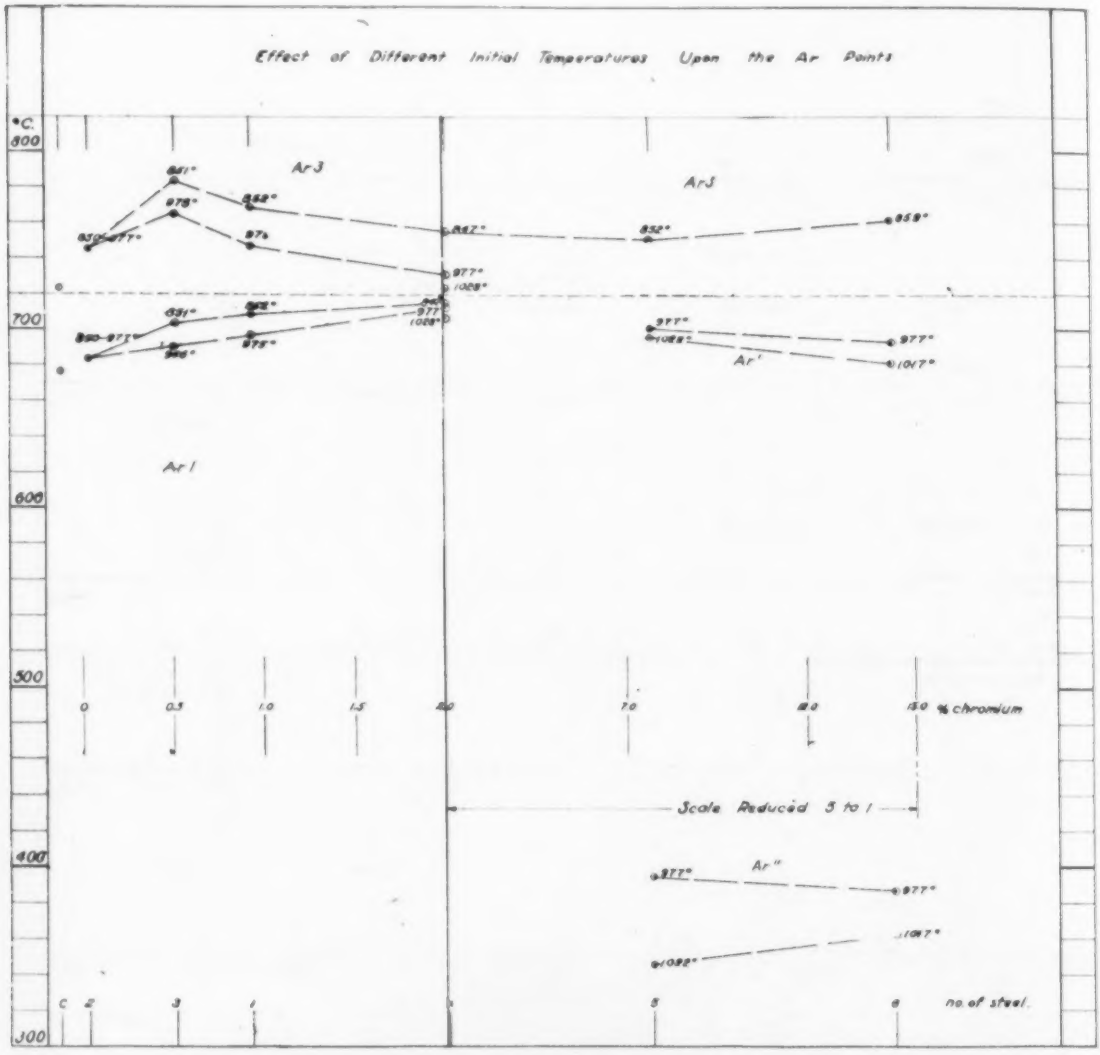
Fig. 12 shows the effect of higher initial temperatures upon the thermal-critical points both on heating and on cooling of the chromium-vanadium steel No. 5 which has the following composition: Carbon, 0.37 per cent; chromium, 14.40 per cent; vanadium, 0.18 per cent.



THE EFFECT OF HIGHER INITIAL TEMPERATURES

Fig. 13 shows the effect of higher initial temperatures upon the thermal-critical points both on heating and on cooling of the chromium-vanadium steel No. 6 which has the following composition: Carbon, 0.42 per cent; chromium, 14.40 per cent; vanadium, 0.18 per cent.

the occurrence of chromium segregates and dendritic growths in casts or rolled steels are frequently met. The difficulty of diffusing these segregated structures is ample evidence of the retarding action of chromium

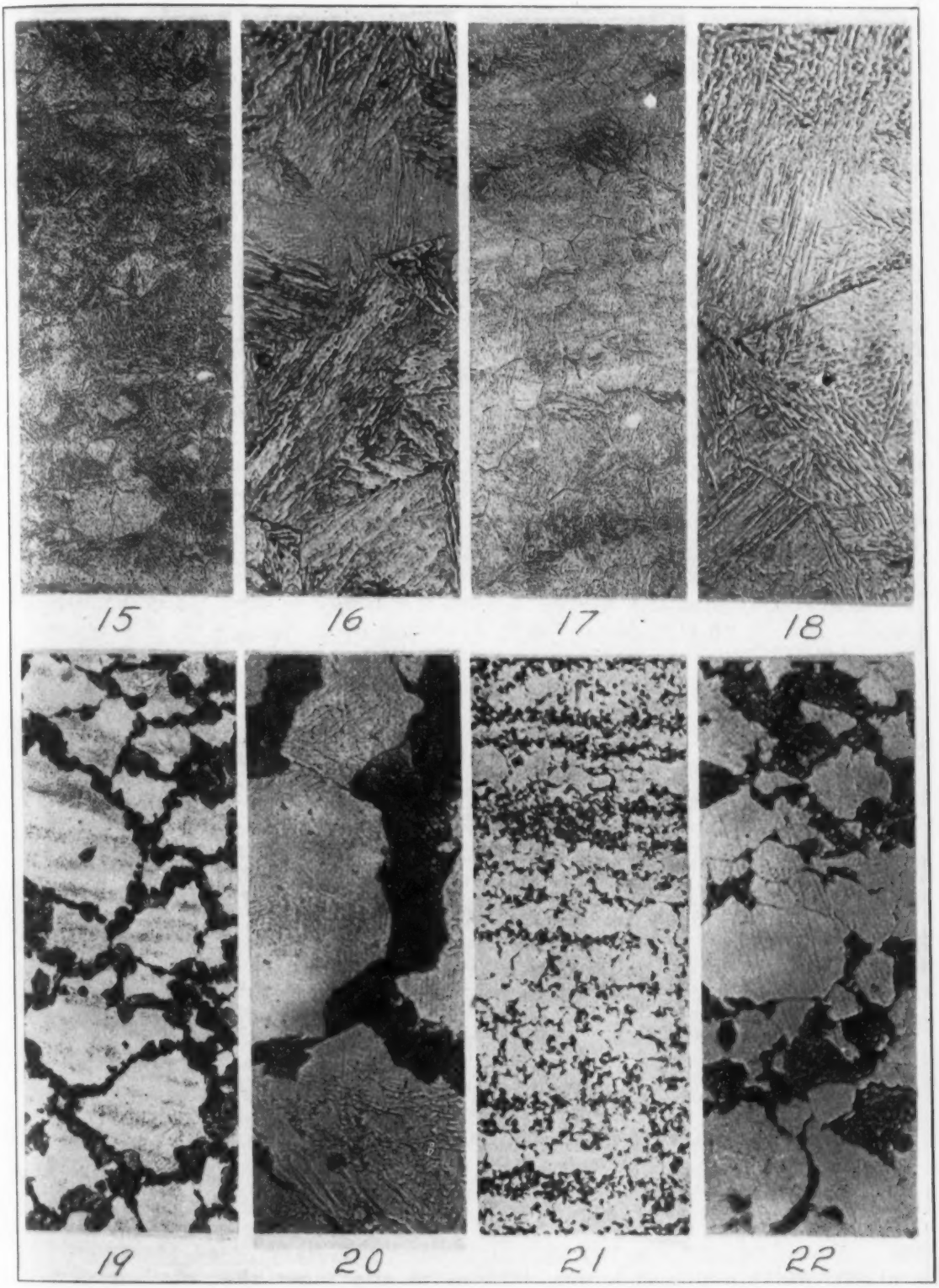


EFFECT OF VARYING INITIAL TEMPERATURES ON THE Ar POINTS
Fig. 14 shows the composite curve of the results shown in Figs. 9 to 13 inclusive.

on the rate at which internal changes progress. The reassociation of carbon atoms into molecular compounds would be correspondingly retarded. A lowering and splitting of the thermal transformations which mark the gamma to alpha change and the formation of carbide, would be expected.

Structure in Critical Ranges

The structure and hardness of the steels undergo important changes with the occurrence of the split transformation. The structures corresponding to various temperature positions in the curves for steels 5 and 6, are shown in Figs. 15 to 34 inclusive. In these steels, the lower or Ar'' transformation is not wholly suppressed by quenching from 1000 degrees



MICROSTRUCTURES

Figs. 15 to 22 show the photomicrographs of the chromium-vanadium steel having the composition: Carbon, 0.33 per cent; chromium, 7.7 per cent; vanadium, 0.18 per cent. All specimens were heated to 1000 degrees Cent. Figs. 15 and 16 were quenched; Figs. 17 and 18 were cooled to 700 degrees Cent. and quenched; Figs. 19 and 20 were cooled to 500 degrees Cent. and quenched; Figs. 21 and 22 were cooled to 350 degrees Cent. and quenched; Figs. 16, 18, 20 and 22, x 500. Figs. 15, 17, 19 and 21, x 100.

Cent. Consequently the structures are martensitic although markings characteristic of austenite are not completely removed. (Figs 15, 16, 25 and 26).

Specimens cooled from 1000 degrees Cent. to a temperature above Ar′ and quenched, retain their martensitic character, but the high chromium steel reveals a precipitation of carbide globules and an apparent diminution in the size of the grains. The grain size change is no doubt, due to the obstructing influence of undissolved and reprecipitated carbides. This evidence of the solution and precipitation of excess carbides in the gamma iron range, does not appear directly in the thermal curves, but is revealed in the thermal effects produced by cooling from successively higher temperatures. Confirmation of the solution is supplied in the increasing hardness with rising quenching temperatures, and the lowering of the transformations as previously mentioned.

Cooling within the range of Ar′, results in the structure shown in Fig. 33. Faint traces of the formation of troostite appear. Below the Ar′ inflection, troostite appears in its characteristic mesh-form occurrence, as shown in Figs. 19, 20, 29 and 30. In steels which show a split transformation, this effect indicates that the changes to alpha iron and carbide (Ar_1) is participating in producing the transformation.

An insight into the nature of Ar″ is partly revealed in specimens quenched at a temperature lying within the range of this transformation. Figs. 21, 22, 31 and 32 show little evidence of a change in the matrix, but within the troostitic areas, a coarsening of the emulsified carbides into the bright specks of Figs. 21 and 22 and the coarsened strings of Figs. 31 and 32 are unmistakable evidence of the coalescence of the troostic components within this temperature range.

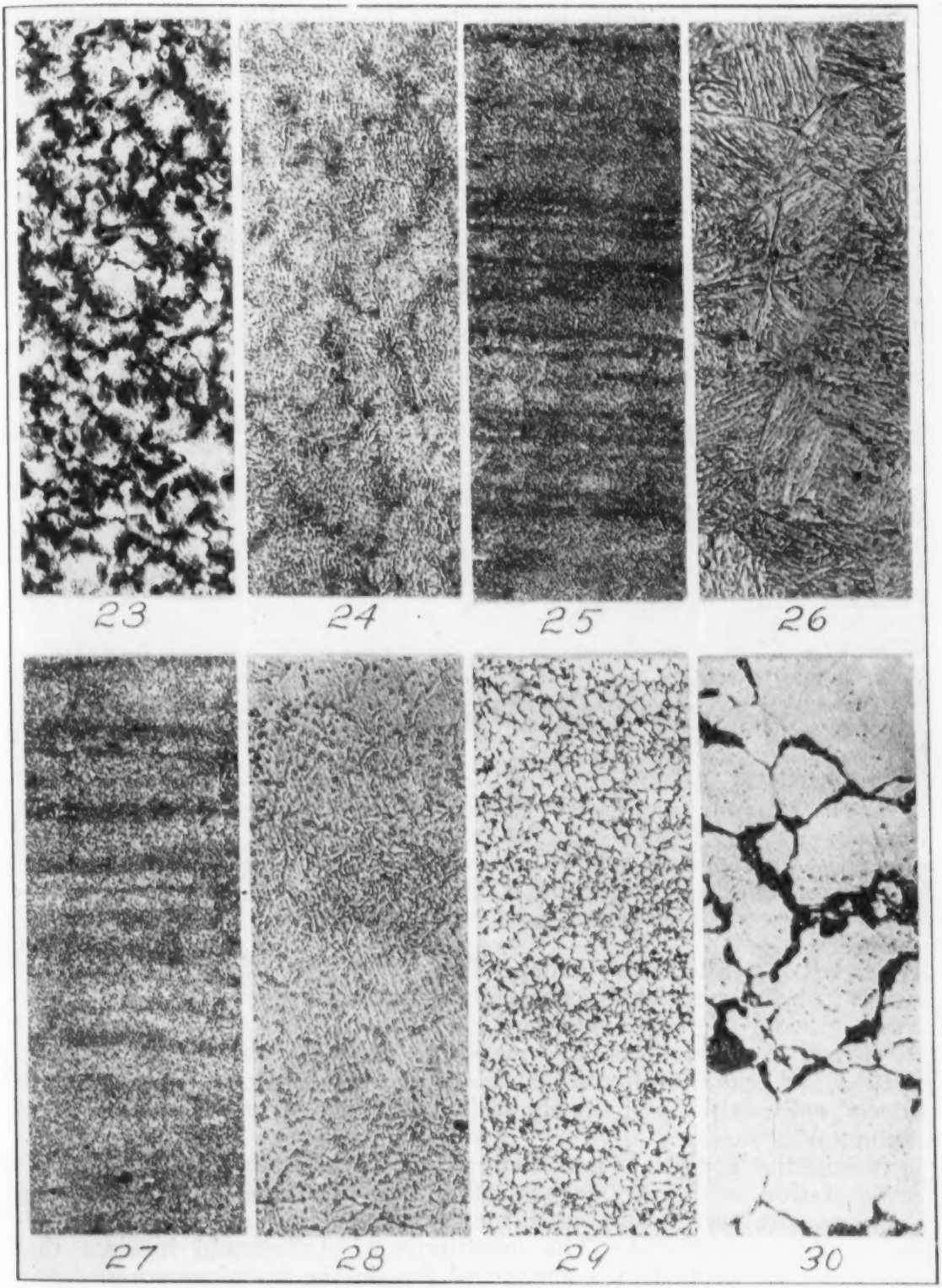
Very slow cooling produces the structures shown in Figs. 24 and 34 which are typical of these usually found in commercial annealed steels of equivalent composition.

The fact that the split transformation is a manifestation of an unstable equilibrium in a super-cooled or super-saturated solution, is sufficient to demonstrate that the structure of any particular specimen is dependent upon the precise condition under which that structure is produced. With this in mind, the structural limits indicated in Fig. 8 have been prepared for the conditions applied. The changes in structural constitution, which would be expected with increasing chromium, are indicated.

Relation of Lowered to Normal Transformations

The split transformations occurring in the above steels, have been recognized by French investigators (namely, Dejean, Portevin, Chevenard) as eruptive to manifestations of the suppressed normal transformations. Opinions as to the exact nature of the split transformation differ. Many of the French metallurgists who have been foremost in the study of this phenomenon, incline to the view that Ar″ is Ar_{3-2} suppressed. Another view held, and recently presented by Honda (19) is that Ar″ is merely Ar′ (Ar_1) suppressed. Difficulties in establishing either view, lie in the inter-dependence of A-1 on A-3.

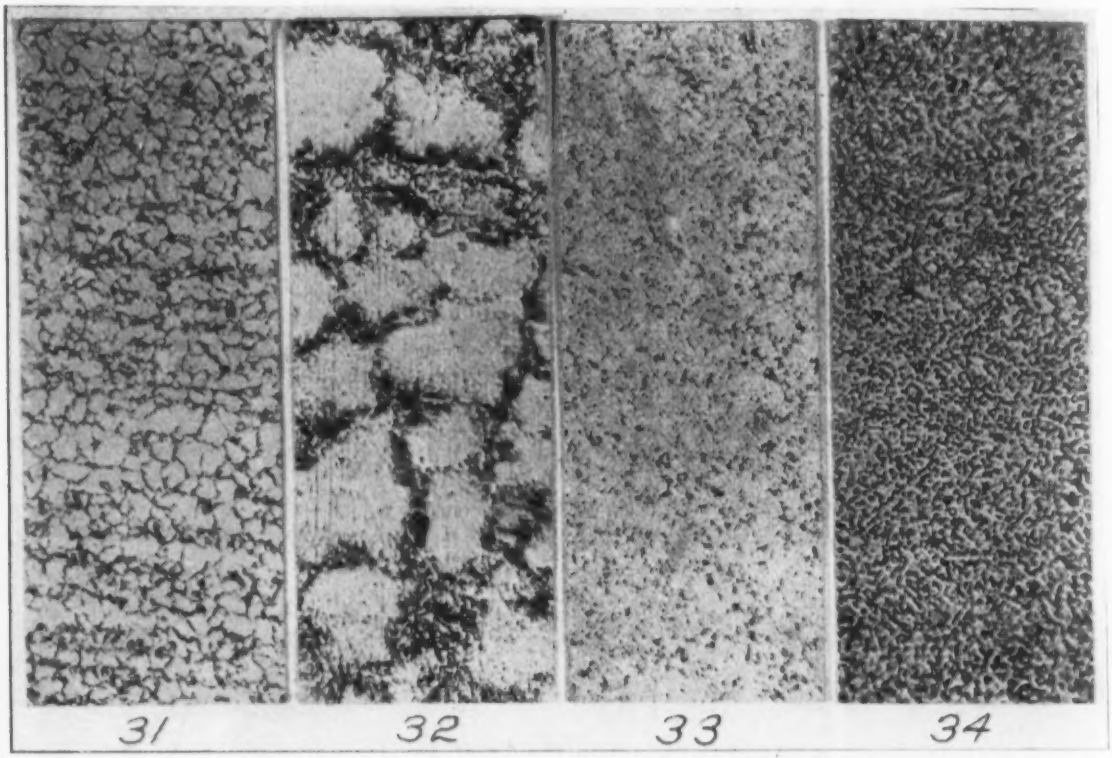
The fact that martensite (18), under suitable conditions, may be obtained as the sole product in a steel in which only the lower trans-



MICROSTRUCTURES

Fig. 23 shows the transition structure in the furnace-cooled specimen showing the split transformation, x 100. Fig. 24 shows the same specimen slightly cooled, x 1000; composition being carbon 0.33 per cent; chromium, 7.7 per cent; vanadium, 0.18 per cent. Figs. 25 to 30 inclusive are the microstructures of the chromium-vanadium steel with the composition, carbon, 0.42 per cent; chromium, 14.4 per cent; vanadium, 0.18 per cent, heated to 1000 degrees Cent. Specimens 25 and 26, x 100 and x 500, were quenched. Figs. 27 and 28, x 100 and x 500, were cooled to 750 degrees Cent. and quenched. Figs. 29 and 30, x 100 and x 500, were heated to 500 degrees Cent. and quenched.

formation occurs, is a strong argument favoring the opinion that Ar″ is the depressed expression of Ar_{3-2}. Again, for steels which are partially austenitic, the same change is operative. In such steels, the upper transformation Ar′ of the split transformation, is suppressed and the



MICROSTRUCTURES

Figs. 31 and 32, x 100 and x 500, show the microstructure of the chromium-vanadium steel of the following composition: Carbon, 0.42 per cent; chromium, 14.4 per cent; vanadium, 0.18 per cent, heated to 1000 degrees Cent., cooled to 350 degrees Cent. and quenched. Fig. 33, x 100, shows the microstructure of the same steel heated to 1000 degrees Cent., cooled slightly below 750 degrees Cent. and quenched. Incipient troostite shown. Fig. 34, x 500; shows the microstructure of the same specimen after heating to 1000 degrees Cent. and slightly cooled.

degree of austenitization is dependent upon the efficacy of the suppression of Ar_{3-2}, which is revealed in the magnitude of the Ar′ transformation.

A condition could obtain, in which the heat absorption at Ac_{2-3}, equalled the heat evolution at Ar″, and the resulting structure appeared entirely martensitic. Obviously, this condition corresponds to that of maximum hardness.

When the conditions are such as to permit the magnitude of the heat evolution at the Ar″ transformation to exceed the heat absorption at Ac_{3-2}, a structure composed of martensite and its decomposition products would be expected. The magnitude of Ar″ would indicate that Ar_{3-2} was accompanied by a portion of Ar_1, in the transformation. Again the occurrence of the split transformation as marked by a distinct upper and lower inflection of the cooling curves, at approximately 700 and 350 degrees Cent. respectively, is accompanied by the formation of a composite structure in which troostite is invariably one of the components. The persistent association of troostite with this phenomenon shows the inter-relation of A-1 and A-3 in such steels. Fig. 23, repre-

senting a corresponding structure, shows the dark troostitic spots blending into the brighter martensitic areas which still retain austenitic features. Since troostite consists of an emulsion of carbide in alpha iron, it is evident that a portion of the gamma to alpha change, (Ar_3) had been spontaneously followed by the Ar_1 change, giving rise to the troostite patches. If the slow change from austenite to martensite accompanying the heat evolution at Ar″ be accepted as the displaced form of Ar_{3-2} when the upper portion Ar″ is suppressed, then Ar_{3-2} would be expected to reappear in the austenitic areas when Ar′ does occur. Figs. 31 and 32 however, shows a precipitation and coalescence of carbides at Ar″ which show that Ar_2 proceeds toward completion at the Ar″ temperature. The obvious conclusion is that Ar_{3-2} and Ar_1 participate jointly in the transformation at Ar″. The structure gradient from troostite toward austenite which is associated with specimens which show the upper and lower transformation, marks the heterogeneous course of the combined, normal, transformation. Fig. 23 described above, is an excellent example of the heterogeneous course of the combined transformations.

Summary

1. The effect upon the thermal transformations of varying the carbon, vanadium and chromium contents of a typical chrome-vanadium steel is described. A pivoting composition of 0.30 carbon, 1.0 chromium, 0.18 vanadium,. had been used to build a series of steels, varying in carbon, vanadium and chromium up to 1.15, 0.60 and 21.0 per cent respectively.

2. The addition of carbon to a chrome vanadium steel lowers the transformations upon heating but leaves them approximately 10-30 degrees Cent. above those for the corresponding alloy-free, carbon steels. Thermal curves indicate that the solution of the alloying elements is practically complete at 850 degrees Cent.; but a slight lowering of the transformations upon heating to 975 degrees Cent. indicates a further solution of dispersion above 850 degrees Cent.

3. The vanadium addition to the carbon-chromium steel, produces very small changes in the usual transformations. Ac_1 is slightly raised, passing Ac_2 at 0.18 per cent vanadium and continuing its rise at the rate of 1 degree Cent. for each 0.02 per cent of vanadium. Ac_3 is lost in the slow progressive heat absorption above Ac_1 that marks the diffusion of the dissociated carbides which were initially, a complex of iron, chromium and vanadium. A complete solution of the alloying elements occurs at a temperature between 850 and 900 degrees Cent. The addition of vanadium tends to lower Ar_{3-2} but Ar_1 remains constant up to 0.30 per cent vanadium.

4. The addition of chromium to the carbon-vanadium steel, slowly raises Ac_1, effecting a junction with Ac_2 at approximately 0.75 per cent chromium. The rise continues, meeting Ac_3 at approximately 3.0 per cent chromium and reaching a maximum at 7.7 per cent chromium. These two composition points occur in the neighborhood of similar critical points reported by Edwards and Murakami, respectively, who

interpreted them as composition limits for corresponding chromium carbides.

5. The pronounced lowering of A_2 when 7.7 per cent chromium has been exceeded, shows the participation of a large portion of the excess to form an iron-chromium solution.

6. The influence of vanadium is obscured in the high chromium concentrations.

7. In cooling, the split transformation occurs when 2.0 per cent chromium has been exceeded and becomes distinct when 7.7 per cent has been added. A further increase suppresses the upper and decreases the magnitude of the lower transformation until a 21 per cent chromium has been added, when but a faint indication of either is detectable.

8. More rapid cooling rates, lower and suppress the transformations as do successively higher, initial, temperatures. The former effect is similar to that produced by increasing the chromium content, and by analogy, is interpreted to show the retarding action of chromium in solution, upon the progress of the transformation. The lowering produced by successively higher initial temperatures appears to be due to the dissociation of the carbides and the dispersion of their component elements, in the iron-chromium solvent.

9. Structures indicate that Ar_{3-2} and Ar_1 proceed spontaneously in specimens which show two distinct (upper and lower) parts of the suppressed transformations. With a suitable composition, the normal transformation may be wholly or partially suppressed in the order Ar_1,Ar_{3-2} by increasing the cooling rate. The results produced are analogous to those obtained by manipulating the less flexible variable, chromium content, or to some degree, initial temperature.

In conclusion, the writers wish to acknowledge the assistance of the Misses Wymore, assistant chemist, and Preble, senior aid, Bureau of Standards, in checking some of the curves and determining the general character of certain experimental variables upon the final results.

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SYMPOSIUM ON METALLURGICAL EDUCATION HELD AT THE FOURTH ANNUAL CONVENTION OF THE SOCIETY, DETROIT, OCTOBER, 1922

IN OPENING this meeting, the chairman, Prof. S. L. Goodale of the University of Pittsburgh, outlined briefly the purpose of the symposium. He stated that the symposium was arranged for the purpose of discussing "not how, but instead what to teach." Numerous written contributions had been received by the chairman in addition to those which were presented by their authors.

The first paper was read by the chairman, entitled

NOTES ON METALLURGICAL EDUCATION

By John A. Mathews

THE incident related in our TRANSACTIONS for September, 1922, in regard to the man who resigned because he "knew enough about steel treating to hold a job any place" is illustrative of a type of mind that is unfortunately not infrequent. This state of mind may result from lack of mental capacity, application, foresight and vision. It may be the result of early environment and lack of educational opportunities, and in many cases can be corrected by intimate association and contact with those possessing vision and enthusiasm for their work.

Presumably this state of mind exists more frequently among the hundreds of heat treaters outside the society than it does inside the society, and we can perform a genuine service for such men by bringing to their attention the opportunities for educational improvement and congenial companionship offered by membership in our organization.

The subject of this symposium, contemplated I assume, a wider view of education, and the part of it which I would emphasize is related to the laying of a foundation. The Good Book records the fallacy of building our house upon the sand. In modern days, the foundation is apt to be none too good because of the expense and poor workmanship. The same applies to the laying of the foundation for specialized education in metallurgy or any other branch of applied science.

The master builders of our great industries in the past generation for the most part were not college men. It is hardly right, however, to say they were "uneducated." Education is not always a matter of schooling, and the school of hard knocks has a brilliant body of alumni. Lack of schooling is not synonomous with lack of mental capacity, and with mental capacity men learn valuable lessons without the aid of books or teachers. While our great captains of industry have been in a narrow sense "uneducated," they have shown their mental capacity by their appreciation of educational training in others in a most practical fashion by their magnificent endowments of colleges and research institutions, and their recognition of the value of education is further evidenced by their selection of assistants and successors.

My own experience and observation lead me to believe that the present

A paper presented before the Detroit Convention Metallurgical Education Symposium, Oct. 3, 1922. The author, Dr. John A. Mathews is president of the Crucible Steel company of America.

tendency is toward too great specialization and beginning specialization upon an insufficient foundation. There is too much anxiety on the part of young men to take special courses of supposedly immediate application in the business of earning money. I believe implicitly in a liberal education as a foundation for professional studies, and as a teacher in a professional school I had an opportunity to compare the men who had such training and those who had not. I have watched some of these men since they graduated and so strongly do I feel the need of a sound foundation that I regret the tendency towards combination courses leading to two degrees in six years. Education in metallurgy, as in all branches of science, should afford the broadest possible training in the fundamental principles of science and economics. The lessons of history, and not the facts and dates of history, are of value. The principles of living and conduct may well be a part of professional education. We must develop the power of reasoning, of intense concentration and of straight line thinking. The mind of the student should be filled with a knowledge of usable principles of conduct, science and economics, and not with a heterogeneous collection of facts. Education should instill in the mind a passion for service, for constructive effort. The desire to serve is a more noble trait than the desire to get. Financial returns should be viewed as the return society makes for well directed creative effort, and not something that the recipient takes from the less fortunate. A broad foundation is necessary because very few students actually know in advance what line of business they will ultimately take up and experience shows that most of them change employment one or more times before getting established. Possibly if their preparation had been all that it should have been so many changes would not be made in the earlier years out of college. The various positions may be considered as post graduate coures in acquiring what was lacking at graduation. In the end, most men get into a place where they can "earn their salt," and if they stick, possibly a little more, until education plus experience bear full fruit. With education that confers a judicial mind, reasoning ability and sound thinking, along with clean living and passion for service, one becomes a powerful instrument for good.

The broad principles underlying metallurgical training are those afforded by a knowledge of chemistry, physics and mathematics, and during the study of these subjects one should acquire a thorough training in what is known as the "scientific method." Certain principles are common to all the sciences, yet each great division requires its own specialized facilities with which the student must be familiar. Improvements in methods of observation, either by new facilities or by new applications of old methods constitute a valuable contribution to knowledge. The invention or application of new and precise appliances aids in the appreciation of the significance of facts and phenomena which were previously obscure and leads us gradually into the deeper penetration of nature's secrets. Metallurgical education should be along lines which will stimulate diligence and accuracy of observation. As Sir William Turner has said "By their application, new facts are discovered and tabulated, their order of succession is ascertained, and a wider and more intimate knowledge of the processes of nature is acquired, but to decide on their true significance a well-balanced mind and the exercise of prolonged thought and reflection are needed. Scientific method consists, therefore, in close observation, frequently repeated so as to eliminate the possibility of erroneous seeing; in experience checked and controlled in every direction in which fallacies might arise; in continuous

reflection on the appearance and phenomena observed, and in logically reasoning out their meaning and the conclusions to be drawn from them. Were the method followed with integrity by all who are engaged in scientific investigation the time and labor expended in correcting errors committed by ourselves and by other observers and experimentalists would be saved and the volumes devoted annually to scientific literature would be materially diminished in size."

For the young man assuming a position, say in the heat treatment of steel, it is unimportant whether he knows the physical properties of the various S. A. E. steels from memory or not. It is unimportant whether he recalls the recalescence temperatures of 1 per cent carbon tool steel. It is vastly more important that he should know the physical and chemical principles underlying the successful practice of heat treatment, and as to the facts, his knowledge should consist, first, of knowing where to find them, and second, the methods for determining them for himself if they are not already recorded. I am convinced that there is a great waste of time and effort in merely duplicating work that has been done and recorded. To avoid this, a knowledge of the literature is important and the instruction in metallurgy should stimulate the interest of the student in regularly and systematically following the current literature as well as referring to the older literature and history of the subject. The processes by which our present knowledge of metallurgy has been acquired and the historic development of processes are of much importance.

In conclusion, I should like to paraphrase the words of Professor Freer written some twenty years ago in regard to the spirit of organic chemistry. What he said is equally true of metallurgy and in the quotation we will take the liberty of substituting that word for "organic chemistry." "No student of metallurgy can afford to neglect the historic side of the question. No one can claim to have absorbed its spirit unless he understands how the knowledge of the present has grown from the toil of the past, and none may expect to create for himself unless he understands the methods and views of his predecessors. In so doing, he must give his whole soul to the task before him. Science is a stern mistress who gives the best within her only to those who follow her unflinchingly, however difficult the task, and however remote the prospects of pecuniary gain or of self aggrandizement, their sole hope being that they too may add to mankind's knowledge of the truth that future generations may profit by the sacrifices of the present. This has been the spirit of the past. It must also be the spirit of the present and future. Science is moving onward swiftly, relentlessly and unflinchingly—no half hearted followers for her—they fall by the wayside. There is no place for those who have not patience to acquire the necessary knowledge. The strong press forward in fierce rivalry, each striving for the ultimate knowledge—a perfect human knowledge, by which from any given premises a logical conclusion may be drawn with unerring accuracy."

Following a few brief remarks by the chairman, H. B. Knowlton, instructor of metallography and heat treating at the Milwaukee Vocational School presented the following paper:

EDUCATION OF MACHINISTS AND TOOL MAKERS IN HEAT TREATING

By H. B. Knowlton

Abstract

Heat treaters, at the present time, are handicapped because of a lack of knowledge of iron and steel, and heat treatment, on the part of some designers, machinists and tool makers. It is suggested that the simplest remedy for this difficulty, is the compulsory education of apprentices of the tool making and machinist trades. During the past year, an apprentice course of this nature has been given in the Milwaukee Vocational School. This paper gives a description of the heat treating department and an outline of the courses. Some of the charts used in teaching the classifications of steel, their properties, uses, and methods of heat treatment, are shown. A brief discussion of the harmful effect of sharp internal angles, is also given. The aim of the course is to train machinists so that they will be able to work more intelligently with heat treaters. Already some of the students have left their trades and gone into the heat treating field. Night courses in heat treating and metallography, are briefly mentioned. Both of these courses are designed for the benefit of the non-technical man. This plan of education is submitted for the consideration of the Society.

AT THE meetings of this society we hear many papers dealing with the errors which may occur in the hardening room, and methods for their elimination. We hear of defects in the steel, pyrometer troubles, quenching media, furnace control, and proper methods for heat treating. It seems to the writer that one of the most common causes for trouble in the hardening room, usually receives too little attention. This is lack of knowledge of the fundamentals of steel and its heat treatment on the part of the designer and manufacturer of parts which are to be heat treated. While there are many designers, machinists, and tool makers, who are well informed on this subject, it is believed that an investigation would show that there are an alarming per cent who do not know the classifications of steel, their properties and uses; who do not understand the reasons for failure in service, nor appreciate the problems of the hardener. If this is a fair statement of the case, then we must admit that the hardener or heat treater is often not to blame for the failures that are charged against him.

Probably most of the members of this society who have worked directly in the hardening room could give many experiences where a lack of knowledge on the part of the designer or manufacturer greatly handicapped them. A typical example from the writer's experience is as follows: Five ball pein hammers were sent into the hardening room together. They looked exactly alike and as they were received from the same man at the same time it was the logical assumption that they were all made of the same material. The maker of these hammers gave us the usual definite information that the material was a good grade of tool steel. After being requested for definite information, he finally said that they were C-Extra. That was all that he could tell us and he thought that he had told the whole story. The five hammers were all given identically the same heat treatment.

After hardening and drawing, two of them were too soft and the other three were still so hard that it was feared that they might chip at the edge. Evidently they were not of the same material. After a thorough investigation we found that three hammers had been made from one bar and the other two from another bar in the same rack. By examining the labels on the bars in that rack it could be plainly seen that the rack contained C-Extra No. 2½, and C-Extra No. 4½. Evidently the hammers which came out the softest were of the lower temper, while the other three were of the 4½ temper, that is they were higher in carbon. On this assumption we hardened and tempered them all again. This time the hammers of the high temper were drawn much further than usual while the others were given only a light draw. The hammers were, of course, treated so as to leave the center much softer and tougher than the face and the pein. This time all of the hammers came out satisfactory. This is merely one example of how a lack of knowledge on the part of the manufacturer handicaps the hardener and how the hardener may vary his treatment and produce satisfactory results, even when the tool is not made of the most suitable steel, if he is only informed exactly what material is used. Undoubtedly you can think of many similar examples in his own experience.

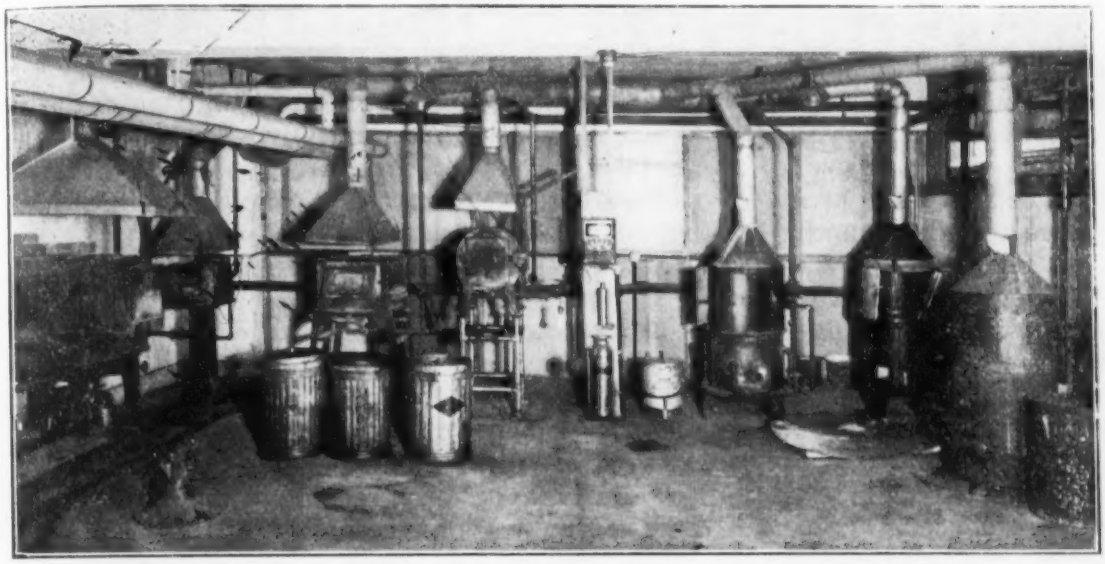
There are two possible remedies for this type of difficulty. First, to educate all machinists, tool makers and designers. Second, for the hardener to determine the composition of every piece which enters his department. This latter can be done accurately by chemical analysis, but this is, obviously, not usually feasible. Of other tests for determining composition, only the spark test on the emery wheel, is worthy of mention. In the hands of the expert this is indeed very valuable. It is doubtful, however, whether the average hardener can tell small variations in carbon content in this manner. Anyone can readily see the difference between very low carbon steel and tool steel.

The heat treater is also handicapped if the designer or manufacturer lacks knowledge of other points concerning steel and its heat treatment. For example, how often do we recive a tool for hardening which has sharp internal angles when it might have been designed with fillets. One old practical hardener said that if we could convert everyone to a "religion of fillets" that a large per cent of our troubles would be over. Does it not seem that one of the most crying needs of heat treaters today is education of everyone who designs or manufactures steel articles which require hardening or other heat treatment?

Granting that the problem of education is important, we have yet to decide upon the best method for teaching designers and manufacturers. It is believed that our Society is accomplishing a great deal along this line. Unfortunately, we can not compel all designers, machinists, and tool makers to join the Society, attend its meetings and read the TRANSACTIONS. It is suggested that we should all do our utmost to interest them in the Society and our problems, but at best we will probably not reach all that we would like to. At the present time, too many do not appreciate the fact that they need any education. It seems to the writer that this problem like many other problems of education, will only be solved by reaching the coming generation. This is what we are attempting to do in Milwaukee by educating the apprentices.

Education of Apprentices

We believe that in Milwaukee we are pioneers in the idea of educating all apprentices to the machinist and tool making trades, in the subject of steel and its heat treatment. Metallurgy and the heat treatment of steel have been taught in colleges and universities for years, but the number reached by the colleges is unfortunately comparatively small. Also it must be considered that the average college student lacks practical experience in the shops, and is liable to be interested in the academic rather than the commercial phase of



One End of the Furnace Room of the Heat Treating Department of the Milwaukee Vocational School.

the subject. It was thought therefore, that it might be of interest to the members of the Society, to describe our work with the apprentices, giving an outline of our course, and stating some of our aims, and what we have accomplished thus far. We will then leave it to your judgment, whether or not our plan is worth while and whether it should be pushed in other places.

The Wisconsin apprentice law requires that all endentured apprentices shall attend a vocational school one half day per week. During this period they are taught mechanical drafting, shop mathematics, blue-print reading and other subjects related to their trades which they would not learn in a thorough manner in commercial shops. They are not taught the operation of machines or other phases of their trade which they are practicing every day in the shops. Thus the vocational school supplements the shop training, by teaching the subjects which the average shops are not in a position to give. The instructors in the vocational school are men who have had both academic education and shop experience. They differ from the shop foremen in that it is their sole business to teach, while the principal duty of the foremen is to keep after production. Teaching the apprentices is liable to be only incidental with the latter.

A year ago the Milwaukee vocational school started a course in steel and its heat treatment for the apprentices to the machinist and tool making trades. It was the original intention to make this compulsory, but up to the present time, this has not been necessary, as we have had a waiting list of those wishing to enter our laboratory sections.

Heat Treating Department of the Milwaukee Vocational School

Our heat treating department occupies three rooms; a lecture room equipped with a stereoptican; a furnace room containing various types of furnaces, a lead pot, cyanide pot, oil tempering furnace, quenching tanks, pyrometer system, etc; a metallographic laboratory equipped with a complete photomicrographic apparatus, polishing equipment, and dark room. Our testing equipment includes Brinell, scleroscope and drop testing machines.

Outline of Course

The course includes both lectures and laboratory work. The lectures are devoted to the manufacture, properties, and uses of wrought iron, and the various kinds of cast iron and steel. The lectures are illustrated with lantern slides. The purpose of these talks is not to give the student a working knowledge of the processes of manufacture, but to teach him what the different materials are and what they should be used for.

The laboratory work covers the following subjects:—the Metcalf test showing the effect of various hardening and annealing temperatures on the grain size and hardness and toughness of plain carbon tool steel; hardening tool steel by the eye to produce the maximum grain refinement: the control and maintenance of furnaces, the construction, use and maintenance of pyrometers; the use of the scleroscope and Brinell machines; the tempering of hardened steel both by color and in oil and other liquid baths; thermo-critical points, methods of determination, importance, and commercial application; effect of expansion and contraction on passing through the critical range; the classification of plain carbon tool steels, their properties and uses; hardening and tempering various commercial tools of plain carbon steel; different methods of annealing; high-speed tool steel, properties and uses, annealing hardening and tempering; air hardening tool steel; fast finishing tool steel; heat resisting and hot die steels; non-shrinking tool steels; other alloy tool steels; the spark test for determining the classification of steel; the effects of oil, water, and air quenching on different steels; the heat treatment of the medium carbon steels; alloy steels of medium carbon; case hardening; the effects of sharp angles; warping and cracking, causes and cures.

It should not be inferred from the above outline that these subjects are taught in the exact order in which they are here stated. Some of the points which are mentioned only once in the outline are brought out over and over in the actual laboratory works as we believe that the only successful method of teaching involves frequent repetition. It is obviously impossible in this short paper to describe in detail how all of these points are taught, but it may be of interest to tell how a few of them are brought out.

Effect of Sharp Internal Angles

Every steel treater knows that square shoulders, counter bored holes, V cuts and sharp internal angles constitute a weakness, but many machinists and tool makers seem to fail to appreciate this point. For this reason we lay great stress upon it. The students are shown samples of commercial failures. In addition they perform the following experiment: A bar of ¼-inch x 1 inch, 1.20 per cent carbon annealed tool steel is bent cold through 180

GENERAL CLASSIFICATION OF STEEL

Carbon Per Cent	Common Names		Properties	General Uses	METHODS OF MANUFACTURE							
					Bessemer		Open Hearth		Electric		Crucible	
					Plain Carbon	Alloy	Plain Carbon	Alloy	Plain Carbon	Alloy	Plain Carbon	Alloy
.00- .05	Very low carb. Dead soft very mild	Ingot iron	Very soft & toug'h Forges cold or hot T.S. 45000	Rivets—Forging stock	Chea forgings Castings, machine parts Building construction	NOT USUALLY MADE	Rivets-Bridges Cars- Locomotives-Autos Boilers - case hardening	Special Alloys—Other Alloys Similar to Plain Carbon Steels—Effect of Alloy		Special Alloys—Low Alloys Similar to Corresponding Carbon Steels—Effect of Alloy		Many Special Alloys Not Given on This Chart
.05- .15		Screw stock hot rolled Cold rolled mach. steel		Forgings and castings-structural steel for bldgs., bridges, cars and Locomotives-flange steel-bars for machined parts-case hardening					Same as		NOT USUALLY MADE	
.15- .25	Low carbon mild-soft								Corresponding			
.25- .35				Parts require slightly greater strength than obtainable with .20% steel					Bessemer			
.35- .45	Medium carbon half hard		Strong & tough some hard'g pw T.S. 85000 An. T.S. 100000 HT	Forgings, castings, and machined parts requiring considerable Strength and toughness	A Rails B C		Shafts-Gears axles-forgings - castings bars-rails		And Open Hearth			
.45- .55	Oil treating								but better			
.55- .65				Heavy R.R. rails-solid wrought wheels-tires-parts requiring Toughness and resistance to wear			Heavy rails		Quality			
.65- .75					NOT USUALLY MADE		wheels tires					
.75- .85			Will harden- will stand ham'r'g	Smiths' tools, hammers, dies, and tools requiring some hardness and great toughness								
.85- .95	High carbon						Lowest Quality Tools		Tools perhaps equal to Crucible Steel Tools		Best Grades of Tools	
.95-1.05	Hard		Willacq. greater hardness but less toughness	Tools requiring greater hardness and some toughness axes, chisels, taps, etc.								
1.05-1.15	Tool Steel											
1.15-1.25			Hard cutting edge	Tools requiring hard cutting edges but not much toughness								
1.25-1.35	Very high carbon		Will become very hard but brittle	Very hard tools-lathe and slotter								
1.35-1.45	Very hard			Very hard tools not requiring toughness								

GENERAL PROPERTIES DUE TO METHOD OF MANUFACTURE				
Chemical Analysis	S .10% Max. P .10% Max.	S .05 Max. P .045 Max.	S .02 Max. P .01 Max.	S .01 Max. P .01 Max.
	Does not weld as well as wrought iron. Not recommended for heat treating. Not as clean or sound as other kinds of steel.	Cleaner and sounder than bessemer	Best and purest grades of steel	

NOTE:

It is the intent of this chart to give only a general idea of the classification of steel. It is impracticable to show all possible kinds of steel on one chart. It is also impossible to draw sharp lines between the classes. Tool steels and special alloy steels are given on other charts. A. S. T. M. and S. A. E. give specifications for construction steels.

degrees without cracking or breaking. The same bar is then nicked with 6 strokes of a hand hack saw and then broken with one or two blows of the sledge. It may be noted that the nick is so small that it can hardly be seen and yet it so weakens the bar that it breaks with very little bending. We find that this simple experiment makes quite an impression upon the students.

Classification of Steel

We also lay great stress upon the classifications of steel and the importance of using the right steel for the job and especially the importance of telling the heat treater just exactly what steel was used. Figs. 4-7 show our blue prints giving the classifications. We try to impress upon the student that the grade or quality of a plain carbon tool steel has nothing to do with the carbon content, and that the carbon content does not tell the price or quality. We call their attention to how the tool steel companies mark their bars, and explain the meaning of the temper numbers. The student is taught that the buyer must co-operate with the steel maker and tell him what the steel is to be used for when purchasing material.

The charts shown herein are only a few of many charts which we employ. The S. A. E. charts, Prof. Keller's charts, critical range diagrams, curves show proper speed of heating, and many other curves and diagrams are also used.

General Aim of the Course

All through our work with the apprentices, we bear in mind that primarily we are training embryo-machinists and tool makers rather than heat treaters. We hope that our boys, as a result of this training, will work more intelligently with heat treaters than some machinists and tool makers do at the present time. Furthermore if any of our graduates do leave their trades and enter the heat treating field, we believe give them a foundation to build upon. If we accomplish this much, we believe that we have contributed something valuable toward the advancement of heat treating.

Other Courses

Besides the course for apprentices, our department gives two more advanced evening courses. The first of these is a course in heat treating, which is intended primarily for men who have had practical experience in the shops. This class meets two evenings per week during the first half of the school year. During the last half of the year, there is given a course in elementary metallography of iron and steel. While there are always a few college graduates in this class, we attempt to give the work in such a simple fashion that it will be entirely within the group of the non-technical man. The main object of this course is to give the practical man the elementary principles of metallography and a reading knowledge of photomicrographs so that he will get more out of the lectures given at the local meetings of the American Society for Steel Treating, and be able to read more easily the articles in the TRANSACTIONS and other technical publications.

Results

As our apprentice classes have only been in operation one year, it is rather early to begin counting the results. However, it may be said that the boys take a very decided interest in the work. Although it was not our

TOOL STEELS

	High Speed	Air Hardening	Fast Finishing	Hot Die Heat Resisting	Non Shrink Oil Hardening	Plain Carbon
Composition	16-18% Tungsten, 3-4% Chromium, 0.5-1.0% Vanadium. Some brands contain Cobalt; some contain higher Vanadium and lower Tungsten	About 10-12% Tungsten	Low Tungsten, High Carbon	Usually low Tungsten, sometimes Chromium and Vanadium	Usually contains about about 1.5% Manganese; sometimes other Alloys	
Properties	Retains hardness and cutting edge when run at a high speed with edge of the tool almost red hot	Will stand considerable reheating after hardening	Takes a very hard, keen cutting edge; will stand a moderate amount of heating after hardening	Will stand considerable reheating without losing its temper	Will retain its size and shape accurately after hardening and tempering	**See Chart of Plain Carbon Steels**
Uses	Tools for use at high speeds	Tools which are not used under quite as severe conditions as high speed	Hard finishing tools for comparatively fast work	Gripping and heading dies for hot work	Dies, Taps and other tools which must retain their size and shape accurately after hardening and tempering	
Hardening Treatment	Heat to 2300°F. Quench in oil: Draw 1100 Cool in air	Heat to 1800°F. Cool in air: Draw as required	Heat to about 1500°F. Quench in water: Draw as required	Heat to about 1500°F. Quench in water: Draw as required	Heat 1400-1500°F. Quench in oil: Draw as required	

NOTE—The composition of different brands of any of the above classes varies somewhat and consequently the proper heat treatment also varies. For specific instructions consult the manufacturer.

PLAIN CARBON TOOL STEELS

Showing Carbon Content, Temper Numbers, Uses and Temperatures for Forging, Annealing and Hardening

Carbon Content Per Cent	Carbon Content and Temper Number Manufacturer or Dealer*														Uses	Temperatures Degrees F. for			
	A	B	C	D	E	F	G	H	I	J	K	L	M		Forging	Annealing and Hardening	Normalizing	Spheroidizing
1.65			A1									7						
1.60			A1		16							7						
1.55			A1		16							7						
1.50			A1		15				1			7		Tools requiring extreme hardness; roll corrugating, chilled roll, turning.		1375 to 1425	1875 to 1925	1275 to 1300
1.45			A2		15				1		7	7						
1.40	6½	6½	A2		14		14			1	7	7	3X	Roll corrugating, chilled roll turning, graver tools.	1440	1375	1800	1275
1.35	6½	6½	A2		14	6	14	XII		1	6½	7	3X		to 1470	to 1425	to 1850	to 1300
1.30	6	6	C2½	2AA	13		13	XII		1½	6½	6½		Lathe, planer, and slotter tools; brass working tools, drawing dies, razors.	1440 to 1470	1375 to 1425	1725 to 1775	1275 to 1300
1.25	5½	5½	C2½	2AA	13	5½	13	XI	2	1½	6	6½	3					
1.20	5	5	D3H	2½XX	12	5	12	XI	2	2	6	6	3	Small taps; trimming and cutting dies; threading dies; circular cutters; forming and boring tools; twist drills; large lathe, planer and slotter tools; woodworking tools; ball races, peening hammers, granite points; edge tools in general.	1450 to 1500	1375 to 1425	1650 to 1700	1275 to 1300
1.15	5	5	D3H	2½XX	12	5	12	X	3	2	5½	6						
1.10	4½	4½	E3	3A	11		11	X	3	2½	5½	5½	33	Milling cutters; taps; trimming dies; reamers; saw swages; circular cutters; mill picks; woodworking; threading dies; granite tools.	1500 to 1550	1375 to 1425	1575 to 1625	1275 to 1300
1.05	4½	4½	H3½	3A	11	4½	11	IX		2½	5	5½	33					
1.00	4	4	K4H	3½	10	4	10	IX	4	3	5	5	Star	Taps, reamers; mining drills; channeling drills; large milling cutters; punches; axes; cups and cones.	1500 to 1550	1375 to 1425	1500 to 1550	1275 to 1300
.95	3½	3½	L4	4	10	4	10	VIII	4	3	4½	5	Star					
.90	3½	3½	L4	4-5	9	3½	9	VIII		3½	4½	4½	4	Punches; large cutting and trimming dies; drop dies for cold work; mining drills; small shear knives; hand chisels; arbors.	1500 to 1550	1380 to 1440		
.85	3	3	M4H	5	9	3½	9	VII	5	3½	4	4	4					
.80	3	3	M4H		8	3	8	VII	5	4	4	4	44	Large shear knives; punches; chisels; hammers; sledges; cold sets track chisels; forging dies; hammer dies; boiler makers' tools.	1600 to 1650	1400 to 1450		
.75	2½	2½	M4H		8		8	VI		4	3½	3½	44					
.70	2	2	N5	Mild Die and Hammer	7	2½	7	VI		4½	3½	3½		Track-tools; smith shop tools; rivet sets; cupping tools; hot drop forging dies.	1600 to 1700	1425 to 1475		
.65	2	2	N5		7		7	V		4½	3							

Typical Analysis

Carbon	As stated
Manganese	.15-.30
Sulphur	Under .03
Phosphorous	Under .03
Silicon	Under .30

*Letters have been substituted for manufacturer's or dealer's name

original intention to turn out heat treaters, already three of our apprentices, who finished serving their time within the past few months, have left their trades and have gone into the heat treating field. One of them is now in charge of a small hardening room, and we are informed that the other two are slated for foremanships as soon as they have had sufficient practical experience. We do not believe that we have done any harm in weaning them away from their trades as their mechanical training will be of great value to them in the heat treating work.

With this we will rest our case, and leave it to the members of the Society to decide whether our major premise, that the crying need of the heat treating science is a more general education, is correct, and whether our plan of solving the problem seems practicable.

Prof. Goodale (Chairman): These enlightening remarks deal with a field that seems to be a very important one and Mr. Knowlton has given us some excellent ideas on the matter. If there are no comments on their paper we shall proceed to the next paper on our program to be presented by Prof. O. A. Knight of Penn State college.

Professor Knight's Contribution to the Symposium

In the school of mines at the Pennsylvania State college, we gave three curriculi, a curriculum for metallurgists, for mining engineers, and for mining geologists. The first two years is the same for all three curriculi. And we believe that there is an advantage in having the first two years the same, because, first, these years are devoted to such subjects as English, mathematics, physics, chemistry, and such fundamental subjects as are necessary as a foundation for the remaining portion of the curriculum, the last two years. And second, it gives a student a chance to study two years, and then decide what he would like to take up, whether he prefers metallurgy, mining geology, or mining engineering.

I might review briefly the last two years of our courses of metallurgy, mining geology, or the curriculum at the college. The first semester in the junior year there are 2 credits required in physical chemistry, 2 in dynamo machinery, 1 in electrical engineering laboratory; 2 in applied mechanics; 3 in assaying; 5 credits in the principles of metallurgy. These involve laboratory as well as class room recitation; and one hour in coking. The second semester: Metallurgical analysis, 3 credits; power laboratory, one; steam engines and boilers, 2; engineering materials, 2; testing materials, 1; metallurgy of copper, 3; metallurgy of iron and steel, 4; stresses in mine structures,—then there is sort of an option between stresses in mine structures and hydraulics. The senior year is devoted, the first semester to electro-metallurgy, 2 credits; electro-metallurgical laboratory, 3; principle of economics, 3 credits; economic geology, 3 credits; alloys and metallography, 4 credits; ore dressing and coal preparation, 3 credits.

The second semester of the senior year: transportation problems; there is an option here between commerce—15 which is transportation problems, and economics—2, current economic problems—2 or political science—13, political parties—3 credits; engineering law, which embodies engineering contracts, 2 credits; metallurgy—74, advanced metallography, 3 credits; and then we have the metallurgy of gold, silver, lead, zinc and minor metals, 5½

Sulphur.....Under .05
Phosphorous.....Under .03
Silicon.....Under .30
*Letters have been substituted for manufacturer's or dealer's name

credits; metallurgical thesis, 3 credits; and mining—78, which is the ore dressing laboratory, 1½ credits.

Now, in connection with that, I might say that an analysis of our entire curriculum shows the following results, and this is what I would like very much to have had in the form of a lantern slide for every one to see. As far as a broad general training is concerned, we try to give it. And as Mr. Knowlton was saying, any suggestions or criticisms I can obtain from anybody here, I would certainly be glad to receive. It would be impossible for you to see this on a small scale, but I would be very glad to show it to any one after the meeting. (Indicating course of study in small type). The title of this, in case you should want it is "distribution of subjects in courses in school of mines, 1921-22, Pennsylvania State college." On this side I have the courses for the freshman, sophomore, junior and senior. Here is the semester; and above is the school in which the various subjects are taught. There is the engineering school, liberal arts, mines, natural science. Then here is a column entitled "common" and under that is "hygiene and physiology and military drill." I will summarize briefly what we have here in the metallurgical curriculum. In engineering, we have 20.3 per cent of their credits; in liberal arts, we have 26.68; in the school of mines, 34.32; in natural science, 13.64; in physical education, hygiene and so forth, 5.33; making 100 per cent in all.

One thing I would like to call attention to here, which might seem odd to some of you, there is only 13.64 points required in the natural science school. That is due largely to the fact that at Penn State, geology is taught in the school of mines rather than natural science which is done in a good many institutions. Likewise, mathematics is taught in the liberal arts which gives a rather high percentage, 26.68 for liberal arts, whereas it is very often included in the natural science group.

Now, I have detailed information concerning just what the various courses are during the different periods, that is, for the freshman, sophomore, junior and senior, for the metallurgist, mining geologist and mining engineers, in the whole table as it is worked out.

We believe in, as you will notice, 26.68 points of credit in liberal arts, and the fact I pointed out, there are the English requirements, and the requirements in economics and transportation problems, in giving as broad an education as possible. Now, our present curriculum is the result of a revision that has been made in the last three years. During the last three years we revised our metallurgical curriculum, and we did so by first writing to the alumni of Penn State, back as far as the graduates of 1896. We wrote to such men as Arthur G. McKee, and H. M. Stuart, the superintendent of blast furnaces at Duquesne; and A. M. Neal, superintendent of the Duquesne Iron works, Carnegie Steel company and from then on down the rank, to the 1918 and 1919 graduates; and we asked them to cooperate with us and to write in and tell us what our curriculum lacks, and what it has in it that we can eliminate. By doing that, we have the present curriculum as it is in the catalog.

I would like to call attention to something that perhaps most of you are familiar with, and that is Bulletin No. 150 of the Mining and Metallurgical Society of America; which is entitled "A Report of the Committee on Technical Education." Most of you, as I say, perhaps are familiar with that; it is by A. H. Rogers, chairman; L. C. Gratton, and A. H. Guest. They have there brought out a good many points. They have pointed out

the distribution of time on a percentage basis, devoted to different subjects in the different schools of the country. And I call your attention here again to Penn State, which is very close. At the bottom of this, there is an average given, an average for all schools; and Penn State does not fall far from the average, but understand, I do not mean to imply at all by that that it is at all perfect, because it happens to fall close to the average.

There was one thing that was mentioned in this report of the Mining and Metallurgical society, on page 183. I will just mention a word about it here. I will not take the time to read it, but I will give you the sum and substance of a part of that page. It states that the metallurgical or mining curriculum is outlined by the faculty of the mining school, and many of the subjects are taught in many other schools, liberal arts, engineering and so forth; and as I have pointed out, they are very often taught with the viewpoint of making specialists in English, or specialists in economics and so on, out of the different men, rather than with the viewpoint that they are to become mining and metallurgical engineers.

We try to get around that difficulty by co-operating with the different departments of the college. We have been co-operating particularly with the chemistry department in the last few years, which was not the case several years ago. The way that is handled is that the chemistry department expects us to give a course in metallography for the special benefit of the chemist and we tell them that we will gladly comply with their request and will be glad to give a course in metallography; providing they will specify what they want taught. In the meantime we expect them to return the favor, and reciprocate by giving us courses in chemistry that will be particularly suitable to the metallurgists.

Another thing I would like to mention is that we are strongly in favor of the senior members of the teaching staff, teaching laboratory work. It is quite common in institutions for the heads of departments and men higher up on the staff to do the lecturing and conduct the recitation work, and allow student assistants and men of inferior rank to take care of the laboratory instruction. We believe that the men higher up should give instruction in the laboratory, because they are in a position to inspire the young men and work up the enthusiasm that otherwise would not be obtained. And, in a metallurgical course anyway, we beleve that the real instruction comes in the laboratory, where you are really doing things.

We also believe in a thesis. We believe every student should be required to work out some problem, and submit a satisfactory thesis before graduation. We think this, because it gives the student an opportunity to show his initiative, and to show what he can do in the way of handling problems of his own. And it is a good experience for him to go after some particular problem, the like of which he may run onto, and no doubt will, when he gets out, and he then has some experience in solving it, together with a little help in solving it, if such help is necessary. The second reason we believe that is a good thing is because it gives the instructional staff, the faculty, an opportunity to pick out the students who will likely make good research men. And as we know from the various research meetings and so on which have been held in the last few years, research men are hard to find, or anyway they are scarce.

If there are any questions that any one may have, I will be glad to make an attempt to answer them. And if not, I believe that this about completes my remarks that I have for this afternoon.

I might add, that we have metallurgical inspection trips specified in our curriculum. The second semester of the junior year is given a four hour course in the metallurgy of iron and steel. At the close of the semester, the students are taken on a two weeks iron and steel inspection trip. During this trip all phases of ferrous metallurgy are carefully studied. Each student is required to hand in a complete report of all operations studied.

During the second semester of the senior year, a course in nonferrous metallurgy is given. At the Easter recess period a two weeks nonferrous inspection trip is taken. Both the ferrous and nonferrous trips are planned by an instructor who accompanies the students and is in charge of the work at all times, and explains the operations observed.

The Mining society, which is affiliated with the American Institute of Mining and Metallurgical Engineers is also an important organization at Penn State. The society is composed of the faculty and students of the mining school. Meetings are frequently held at which times prominent mining and metallurgical men are secured as speakers. This brings the student in contact with practical operating men.

If a student wishes to spend five years, he is given an opportunity to study for the degree of Master of Science which may be obtained in one year after the degree of B. S. in metallurgy has been obtained provided the required amount of work is satisfactorily performed.

The degree of Metallurgical Engineer is given to four year graduates of Penn State after they have been in responsible work for at least three years and have submitted a satisfactory thesis.

Discussion of Professor Knight's Contribution

Mr. Thum: I would like to ask what was eliminated from your curriculum as a result of the questionnaire.

Prof. Knight: I am sorry I do not have all of the old catalogs.

Mr. Thum: In general, what did you eliminate as being non essential and what did your graduates regard as being essential?

Prof. Knight: There was one subject that we did not eliminate although there was considerable debate upon the matter, and that was the course in "stresses in mine structures." Most of the men seemed to be of the opinion that this course should not be eliminated. So that, instead of eliminating the course we made an optional between stresses in mine structures. Hydraulics-1 and laboratory-3. This is one of the things that we made flexible.

Another thing that we eliminated was the course for geologists. They were having a little too much geology, and we thought we could eliminate geology and put in advance metallography. Now, they have eight hours laboratory work in the second semester. If I had an old catalog, I could give you everything and would be glad to; if you should be particularly interested, I could look that up and give you the whole thing in detail. Are there any other questions?

Mr. Thum: May I ask if there was anything added besides an advanced course in metallography, and if the work in economics and such allied subjects were also partly due to this questionnaire?

Prof. Knight: The work in economics I believe has been in the curriculum for a number of years.

Prof. Upthegrove: The credit hours were increased?

Prof. Knight: The credit hours in economics were increased. There were about one and one half hours before, and it was increased to three credit hours now.

Prof. Goodale (Chairman): The next speaker on our program is D. R. Campbell.

Mr. Campbell's Contribution

One of the first problems a metallurgist is confronted with when placed in charge of a heat treating department is to make a study of the equipment in use, in order to determine whether the most efficient furnaces, burners of fuel, pyrometer equipment, quenching tanks and so forth, are in use; in order to attack this problem in the best possible manner, it is necessary to know the principles of furnace construction, of the different type of burners, and methods for determining fuel consumption and so forth.

A university course in heat treating, and room equipment would be of immense practical value to the embryo metallurgist. This course should not only be a lecture course, but should contain laboratory sessions at which the students are allowed to build furnaces, oil, gas and electrically heated and required to determine comparative fuel costs, study various methods of cooling, quenching mediums, and so forth. Such a course should be made compulsory for all students studying chemical and mechanical engineering.

Prof. Goodale (Chairman): Does any one have any remarks to make on this contribution?

Prof. Boylston: Prof. Goodale, I am sure that Case school would be very glad to inaugurate such a course, if the manufacturers would kindly donate the machinery.

Prof. Goodale: If there are no further comments, we shall now call upon Prof. H. M. Boylston of Case School of Applied Science for his paper entitled:

A COURSE IN METALLURGY FOR METALLURGICAL ENGINEERS

By Prof. H. M. Boylston

Steel treaters, manufacturers, employers, chemists, teachers, students, men-at-the-fire, highbrows, theorists, drop forgers, metallurgists, and all others interested in metallurgical education, I bring you greetings from Case School of Applied Science, Cleveland, O., where we train men whom some day you may employ. I am speaking particularly for the department of metallurgical and mining engineering, formerly called the department of mining engineering and will deal only with the course leading to the degree of Bachelor of Science in Metallurgical Engineering.

In my nineteen years of teaching experience I am quite sure that this is the first time I have ever been asked to attend a symposium on metallurgical education. Great credit should be given our American Society for Steel Treating for bringing this symposium about. An exchange of ideas should be encouraged between team captains and coaches, practical men and theorists, employers and teachers as to what

we should teach those men who will some day have to design metallurgical plants, heat treatment departments and laboratories, or manufacture automobiles, airplanes, ordnance equipment, engines, automotive equipment and other high quality steel products without number. I believe you will all agree with me that heat treatment of steel implies quality of product and quality of product requires carefully trained men.

I am going to try to show you in the few minutes which I have at my disposal what we are attempting to do at Case School of Applied Science for those who have selected the profession of metallurgy. A few slides will be shown to illustrate my remarks.

The first slide is a tabular view of the courses prescribed for first year students, and you will note that there are no metallurgical courses listed; in fact the freshman year is the same at Case for all departments.

Course in Metallurgical Engineering

FRESHMAN YEAR

Subjects	Weeks	Hours per week
FIRST TERM		
Trigonometry—Mathematics 2	17	5
French—Modern Languages, 40	17	3
Principles of Exposition—English 31	17	3
General Chemistry—Chemistry, 601	17	3
Chemical Laboratory—Chemistry	17	4
Mechanical Drawing—Drawing, 81 / Descriptive Geometry—Drawing, 82	17	10
Gymnasium	17	2
SECOND TERM		
Analytic Geometry—Mathematics, 3	17	5
French—Modern Languages, 41	17	3
Argumentation and Debating—English, 32	17	3
General Chemistry—Chemistry, 601	17	3
Chemical Laboratory—Chemistry, 602	17	4
History	..	1
Mechanical Drawing—Drawing, 81 / Descriptive Geometry—Drawing, 82	17	10
Surveying—Civil Engineering, 101	17	1
Gymnasium	17	2
PRACTICE TERM		
Topographic Surveying—Civil Engineering, 101, 102	4	44

Figures in bold face type represent laboratory work; others, class room work.

We do, however, give all freshmen a great deal of mathematics including trigonometry in the first semester. Analytical geometry in the second and descriptive geometry and mechanical drawing throughout the year. In the second semester a class room course in the principles of surveying is given. For four weeks during June the whole freshman class takes practical topographic surveying in the field at Camp Case, near Waynesburg, in central Ohio. The camp is situated close to several coal and clay mines. The freshmen also have French and general chemistry during the entire year, with corresponding laboratory work in the latter. Last, but not least, they are given one semester in the principles of exposition and one semester in argumentation and debating. These courses in English are given by a man familiar with the English and public speaking needs of engineers.

In the Sophomore year mathematics is continued with a course in

Course in Metallurgical Engineernig

Subjects	Weeks	Hours per week
SOPHOMORE YEAR		
FIRST TERM		
Calculus—Mathematics, 5	17	5
Spanish—Modern Languages, 50	17	3
Mineralogy—Geology and Mineralogy, 71	17	2
General Physics—Physics, 501	17	5
Mine Surveying—Mining Engineering, 402	17	2
Mine Drawing—Mining Engineering, 401	17	6
Physical Laboratory—Physics, 502	17	6
Mineralogy Laboratory—Geology and Mineralogy, 71	17	3
Gymnasium	17	2
SECOND TERM		
Calculus—Mathematics, 6	17	4
Spanish—Modern Languages, 51	17	3
General Physics—Physics, 501	17	4
Applied Mechanics—Applied Mechanics, 21	17	4
Qualitative Analysis—Chemistry, 605	17	2
Physical Laboratory—Physics, 502	17	6
Qualitative Analysis—Chemistry, 605	17	6
Gymnasium	17	2
PRACTICE TERM		
Mine Surveying—Mining Engineering, 403	4	44

Course in Metallurgical Engineering

Subjects	Weeks	Hours per week
JUNIOR YEAR		
FIRST TERM		
Introductory Metallurgy—Mining Engineering, 407	17	2
Assaying—Mining Engineering, 409	17	1
	17	8
Applied Mechanics—Applied Mechanics, 22	17	4
Quantitative Analysis—Chemistry, 608	17	2
Physical Chemistry—Chemistry, 607	17	2
Elements of Electrical Engineering	17	3
Electrical Engineering, 305	17	3
Quantitative Analysis—Chemistry, 608	17	9
Gymnasium	17	2
SECOND TERM		
Metallurgy—Mining Engineering, 418	17	3
General Geology—Geology and Mineralogy, 72	17	5
Hydraulics—Applied Mechanics, 25	17	3
Technical Exposition—English, 33	17	3
Elements of Electrical Engineer.—Electrical Engineering, 305	17	3
	17	3
Quantitative Analysis—Chemistry, 608	17	1
	17	6
Petrograph—Geology and Mineralogy, 73	17	6
Gymnasium	17	2
PRACTICE TERM		
Mining and Metallurgy—Mining and Engineering, 411,426	4	44

Figures in bold face type represent laboratory work; others, class room work.

calculus, throughout the year. Spanish is also given throughout the year; mineralogy with laboratory work and general physics with physics laboratory are also given throughout the year. A course in

Course in Metallurgical Engineering—Metallurgical Option

SENIOR YEAR

Subjects	Weeks	Hours per week
FIRST TERM		
Business Correspondence—English, 35	17	3
Economics—Miscellaneous, 97	17	2
Determinative Mineralogy—Geology and Mineralogy, 75	17	2
Metallography—Mining Engineering, 420	**17**	3
Metallurgical Laboratory	**17**	6
Ore Dressing—Mining Engineering, 405	17	3
Hydraulic and Testing Laborat.—Applied Mechanics 24 and 26	**17**	3
Mechanical Engineering of Steel Plants, Mechan. Engineering, 249	17	2
Gymnasium	**17**	2
SECOND TERM		
Metallurgy—Mining Engineering, 424	14	3
Physical Metallurgy—Mining Engineering, 427	14	2
Mining—Mining Engineering, 404, 408	14	4
Power Plant Engineering—Mechanical Engineering, 241	14	3
Mine Law, Business and Administration—Mining Engineering, 412. Optional with Geology, 74	14	3
Economic Geology—Geology and Mineralogy, 74	14	3
	14	3
Electrometallurgy—Mining Engineering, 425	14	3
Engineering Laboratory—Mechanical Engineering, 247	**8**	3
Thesis—Mining Engineering, 431	..	..
Excursions—Mining Engineering, 430	..	15

Figures in bold face type represent laboratory work; others, class room work.

the theory of mine surveying is given in the first semester. A course in applied mechanics and one in qualitative analysis with laboratory work, is given in the second semester. In June the combined class of miners and metallurgists take a course in practical mine surveying at Camp Case or elsewhere, performing operations in both surface and underground surveying with the preparation of topographic and mine maps.

In the junior year metallurgical subjects are given for the first time and you will see listed in the first semester, introductory metallurgy which includes pyrometry, calorimetry, typical metallurgical equations and processes, a study of fuels and refractories, physical properties of metals and alloys, etc. Courses in fire-assaying, applied mechanics, quantitative analysis and physical chemistry are also given in the first semester with a course in the elements of electrical engineering lasting throughout the year. In the second semester courses are given in the descriptive metallurgy of iron and steel, general geology, hydraulics, quantitative analysis and petrography, and last but not least a course in technical exposition, (a study of technical writing). In the June practice term, so called, the program is varied; sometimes the metallurgists visit mines with the class in mining and sometimes they visit purely metallurgical works. A year ago last June the class visited iron and copper mines in the Lake Superior region and steel and silver plants in the vicinity of Chicago and Cleveland; while this year, on account of the high cost of traveling, the class visited steel works in Buffalo, Syra-

cuse, Pittsburgh, Woodlawn and Colona, Pa., Youngstown, Canton and Cleveland, O., where some of the members of our society received the class with gratifying courtesies. This trip is an inspection trip and the students do not work at any of the plants, although they are urged to spend their summer vacations in practical engineering work from the time they begin school.

In the senior year, metallurgical students have a course in ore dressing with laboratory work, hydraulic and testing laboratory, mechanical engineering of steel plants, determinative mineralogy, economics, nine hours per week in the metallurgical laboratory where they determine calorific values of fuels, melting points of pure metals and alloys, learning the use of various forms of pyrometers and performing other experiments involving simple heat treatments of steel. This year we are going to include in this course for the first time, certain laboratory experiments carried out at Harvard university for some years and described in a little note book called, Laboratory Experiments in Metallurgy, by Sauveur and Boylston and published originally in 1908. The following experiments are included:

1. Coking and proximate analysis of coal
2. Calorimetry
3. Pyrometry
4. Melting point of tin, lead and zinc
5. Reduction of copper oxide by carbon
6. Reduction of lead oxide by carbon
7. Reduction of copper oxide by copper sulphide
8. Reduction of lead oxide by lead sulphide
9. Determination of thermal critical points of steel
10. Changes in magnetic properties occurring at the thermal critical points
11. Relation between the critical points and the hardening power of steel
12. Hardness produced in high carbon steel by quenching
13. Influence of carbon upon the hardness and hardening power of steel
14. Influence of the nature of the quenching bath upon the hardening of steel
15. Tempering of hardened steel
16. Effect of annealing upon the properties of cold worked steel
17. Modified Metcalf experiment to show the effect of quenching from different temperatures upon the fracture of steel

In this course also, the students prepare for their thesis work which comes in the second semester. In the first semester courses in business correspondence and in the metallography and heat treatment of iron and steel are given. The latter course devotes 3 hours weekly to lectures or quizzes and 6 hours per week to laboratory work, for 16 weeks, and the well known metallographist's bible, written by one of our honorary members, Professor Albert Sauveur, of Harvard university, is used as a text. In the second semester the metallurgists are required to take a course in the descriptive metallurgy of copper, lead, gold and silver, zinc and tin, and a course in electro-metallurgy about half of which is devoted to the electro-metallurgy of iron and steel.

I have inaugurated a new course, known as physical metallurgy,

and am using for a text the second volume of Dr. Hoyt's book entitled, "Metallography; Metals and Common Alloys," so that the students may have some instruction in non-ferrous metallography and the more recent metallographic theories. The seniors also have power plant engineering with laboratory work and a short course in mining. They have the choice too, of a course in mine law or in economic geology. About half the time in the second semester is devoted to a thesis, that is, the working out of some metallurgical problem; this time during my brief residence at Case has in nearly every instance been devoted to the heat treatment or the metallography of iron and steel.

I wish we had a fifth year at Case. The four years work leads to the degree of Bachelor of Science in Metallurgical Engineering but metallurgical engineers should be trained in metallurgical design, should have further experience in heat treatment and the design of heat treatment furnaces, and furthermore should have about one-half year more devoted to research or thesis work.

During such a fifth year, special attention should also be given to the writing of technical papers and reports, for we believe here at Case, that it is impossible to devote too much time to the study of our own language. The engineer is often handicapped by failure to express himself properly and thus is unable to sell his ideas to his employers or to the public. At present the policy of the school is to give a student the degree of Metallurgical Engineer, only when he has received his degree of Bachelor of Science in Metallurgy and has in addition had three years of active metallurgical experience in fairly responsible positions. He must also submit a special thesis on some metallurgical subject. There have been a few cases where men have returned to Case for a fifth year, devoting half of their time to research work and the other half to special courses, but at present the degree offered to these men is the degree of Master of Science in Metallurgical Engineering.

I should like to read an extract from the Case Handbook prepared by C. L. Eddy, professor of railroad engineering, for the Boost Case association. This booklet is handed out to every freshman as he enters college in the fall.

Value of Participation in Student Activities

"While it is recognized that the scheduled work of the curriculum is the important work of the student while in college and that nothing should seriously interfere with that work, still it is believed that there is a value derived from the participation in student activities and that it is well worth the extra effort that it requires.

A man's success in the business world depends upon many things besides the grades he has made while in college. Since we live in a world of other men, in order to make our way, we need, besides a disciplined mind, many other qualities, such as knowledge of men, tact, personality, perseverence, energy, enthusiasm, power to concentrate, ability to work hard and effectively and above all, character.

Emerson has said that a boy goes to college to be taught by his professors, but that it is his classmates who educate him, a statement with some foundation in truth, if by an educated man we mean one who,

besides having a disciplined mind and knowledge, is well developed in those other qualities just mentioned.

It is believed that participation in school activities helps to develop in a man those qualities which are so essential to his success in after life- - - -."

In closing, let me thank you for your attention and let me add that I shall be very glad, indeed, for suggestions either orally or in writing as to how this course may be improved. We realize that we are not turning out metallurgical engineers, but raw material from which the metallurgical plant or its departments can produce the finished product. I think all of you will admit and we do likewise, that raw material is a good name for some technical graduates, but admitting this is half the battle and it then becomes a matter of the degree of rawness. This is the point in which you and we alike are interested, namely, the quality of our graduates and for the improvement of the quality we appeal to you for your co-operation and support.

Prof. Goodale (chairman): That is very good. Each of our speakers have brought out some very excellent ideas of interest and value to all of us. If there is no discussion we will now hear from Col. A. E. White, of the University of Michigan.

Colonel White's Contribution

Prof. Goodale, and gentlemen: I really did not intend to say anything at this meeting, because I think Prof. Upthegrove and Prof. Wood can say something which would add possibly more to this subject than I can. We are of the opinion, however, at the University of Michigan, that we have attempted to give our men, in a four years' course, somewhat too technical a training, and have not given due consideration for the humanities. We realize that in four years' time we cannot turn out an engineer. We wonder if we are treating the boy quite fairly if we give him only engineering, with no background such as would be given to him by history, or such as would come to him by a study of economics and matters of business administration. For that reason, therefore, the work at the University of Michigan in the lines of civil and mechanical and electrical engineering, and metallurgical engineering, bear great points of similarity. We believe that we attempt there just to give a very broad general training in the general field of engineering, with enough of the humanities so that he is a broad gauged man when he leaves school. We are attempting to give him these specialized subjects in his fifth year; and we are making every possible inducement to get the men to remain over for a fifth year.

We are making a special effort to get industrial companies to establish fellowships at the university so that one half of the man's time can be devoted to engineering lines outside of that in which he is specializing, and one-half can be devoted to the technical line in which he is specializing. That is our thought, and that is our purpose. We are trying to do this in such a way as will not wreck the engineering college, because we are not quite convinced that the time is quite here for making the engineering program for our university a five year program. We have seen what has happened in other schools that have attempted to do it, and we know that the attendance has immediately dropped to negligible quantities. Yet, on the other hand, we see the

tendency among the medical schools and dental schools to raise the plane of instruction, which has not been to increase the technical work, but rather to give the man a broader background in the humanities, so that he is a broad-visioned man when he leaves the school. That is the reason we are working on this general program.

I hope all of you can come out to the university. I would be glad to show you what we are trying to do. We are engaged in a great building program. I believe there are something like eight buildings being erected at this moment in Ann Arbor, at a total aggregate cost of something like five millions of dollars. Our president is not at all convinced that our facilities are today adequate. In fact, I know he is going before our legislature, and try to convince them that we need fully five million dollars more for our next two years building program. Of course we realize that we have something that the endowed schools do not have, and the endowed schools have something that we do not have, and that is a difference possibly in the sources of the income. However, I will not go into those subjects right now. They are totally divorced from the subject at hand. I will just try to give you gentlemen an idea of the purpose with which our instruction is carried out. Prof. Upthegrove can give you the different details.

Today one of the speakers has spoken of a proper course and curriculum. I wonder if you will agree that we are right in trying to broaden the course, and introduce more of the humanities, or should we narrow it and turn out a man highly specialized but without the viewpoint of life that he would have if he had the humanities, if we try to put these things into four years. That is just the thought, men, that I have today.

Prof. Goodale (Chairman): We will now hear from Prof. D. J. Demorest of Ohio State university.

Professor Demorest's Contribution

Mr. Chairman, I think the most effective thing that we can do for bettering our work, in whatever line it may be, is by meeting together and talking, and listening to each other's talk and personal discussions.

I come from Ohio State university, the department of metallurgy, and I would like to add this one little point to the discussion. We have a four years' course in metallurgy, with the degree of Master of Metallurgical Engineering as most courses do. We have a curriculum committee which met on an average of once a week for about two hours for about two years. The purpose of that curriculum committee was to discover everything that we might do in order to better our curriculum in the college of engineering, in the university, and to bring us in every way abreast of the times.

Of course, as to this five year course, the five year curriculum idea was under very complete discussion. We finally decided to go on with the four year basis, having changed the college from the semester plan into the four quarter plan. It runs now four quarters, the year around, offering students twice a year every course in the freshman and sophomore year, so that the man who gets out of step can get back into step and not lose time. We open up in our junior and senior years some courses; in the senior year we have one elective course, so that the students who need special training along the lines of economics,

business administration, factory management and so forth, can get those courses in the senior year, and in the junior year they can get some courses by advising with their teacher. A student cannot elect a course without permission from the head of the department under whom he takes the most of his work. Any student who is deficient in his English, of course, is required to elect English—if that can be called an election.

Now, as to this fifth year, it has bothered us a great deal as to what to do about it. We believe, and I think it is true that if the teachers, the faculty members who teach civil engineering courses, always have as a background of their teaching and always have as the underlying purpose of their teaching the training not merely of engineers, but the making of citizens; and all of their teaching is colored by the spirit that an engineer, in the course of his four years, gets a very thorough training in the humanities, and it makes for good citizenship, after all perhaps even better than if you took a regular classical standard set of courses in history and economics, much as those things are desirable. Now, that gets right down, of course, to the responsibility of the president of colleges, and deans of institutions, the deans of colleges in their selections of faculty members. A faculty member should not be selected merely because he is a keen technologist, but because he is known to have the real spirit of education in him. And I think that if that sort of thing is carried out carefully, and without deviating from that basis of selection of teachers, that an engineer in his four year course is going to be just as well trained in the broad and proper outlook of the citizen as if he had taken a number of formal courses in the arts college. I think the five year course would be better, if the cost were not too great to the students so that it would not eliminate a good many fellows who should get a degree in engineering, who are worthy of it, and all of that sort of thing. I believe that the real training in manhood and citizenship as well as technical keenness and research ability, can be done in four years, if we apply ourselves to it, keeping always as our background that we are not merely turning out an able chap, but a real chap, a real man.

Prof. Goodale (Chairman): If there is no discussion we shall now call upon J. M. Watson of the Hupp Motor Car corporation for his paper, entitled:

PRACTICAL ASPECTS OF METALLURGICAL WORK

In a manufacturing concern such as a truck factory, washing machine plant, passenger car factory, etc., the metallurgist is looked upon as the watch dog of quality, and he is regarded as the logical man, not only to keep the quality of the product at its highest peak, but also to impress upon the other departments this idea of quality and see that these other departments pass this thought along to the doing the actual work and the outside concerns with which they come in contact.

The work of the metallurgist comes in direct relation with the following departments: engineering, purchasing, manufacturing, sales and service. The men in these departments are not educated nor trained along metallurgical lines and it is necessary to deal with them along practical lines, and talk in non-technical language. Hyper eutectoid,

spheroidized, recalescence, etc., sound nice, but don't mean anything to them.

In order to point out more clearly what is meant, each of the departments mentioned will be taken individually and the connection between it and the metallurgist briefly shown.

Engineering Department

In addition to his usual engineering duties, the metallurgist should be in a position to criticize the design of the component parts of the final product, that is, he should be able to point out the weak points in a forging, where cold shots are liable to occur, difficulties that may be encountered in heat treating, due to sharp corners, unequal distribution of metal, insufficient metal around stud holes, etc. In castings, to pick out places where there is danger of shrinkage cracks; difficulty in pouring, or poor arrangement of cores. In stampings, he should pick out difficulties in sinking dies, show where stampings will crack in the die, and point out difficulties in machining. In case of machinery or motor driven vehicles a study of the various types of oil and lubricants is essential. The metallurgist should be in a position to not only make the ordinary routine oil and grease analyses, but should have a general knowledge of their lubricating properties when put in actual use.

To sum up, he should be able to give the designing engineer not only complete data concerning steels or other metals to be used, but should give also information regarding the economical manufacture of the part and difficulties which are liable to be encountered in the fabrication of the piece.

Purchasing Department

When the purchasing department is contemplating placing an order with a concern for forgings, screw machine parts, stampings, etc., the metallurgist is the logical man to be sent to investigate the plant. First he is primarily interested in the steel and its heat treating, but when making his report he should also take into consideration the fire risk in the buildings, the condition of the machinery and its arrangement: the type of work done, the methods of inspection, and the shipping facilities.

To fit the metallurgist to do this, it is suggested that when university classes are taken on tours of inspection, that the student be instructed to observe non-metallurgical points as well as those directly concerned with his studies. An excellent heat treating plant, and a first class steel stock mean nothing if the buildings are fire traps, or the work is not properly inspected when completed.

He should also follow the trend of raw material prices closely and give advice as to the best time for buying.

Manufacturing Department

Coming in contact with the manufacturing department the metallurgist must be in a position to give advice not only concerning the heat treatment of tool steels, but also the shape of the tool, the cutting speed, the most suitable lubricant to use, and various things of this nature. To fit him for this, more time should be devoted to practical work in machine shop practice.

Usually the head of the machine shop will know most of these

things from long experience, but many times in case of trouble the metallurgist is called in consultation and he should be in a position to give advice.

Sales Department

Having assisted the engineering department in designing the part according to good metallurgical practice, helped the purchasing department to pick satisfactory sources of supply, and aided the manufacturing department in the fabrication of the machine, it is up to the metallurgist to sell the sales department from a quality standpoint. In order to do this the metallurgist should have a good foundation in English and have been instructed how to express himself clearly and understandingly without the use of technical terms that mean nothing to his hearers.

Recently a professor from the University of Michigan said that he thought the reason the engineer did not take his proper place among the professions in public opinion was the fact that he is content to do things in a quiet way without the public realizing that he has really accomplished a wonderful feat. In other words the engineer devotes so much time to strictly technical work that he neglects the public side of his profession.

Instructing the sales force to point out the value of the product from a quality standpoint, giving details which can be passed on to the ultimate consumer is an asset that makes the metallurgist invaluable to his concern.

There is one thing that I would like to add here. In a law school, you walk in and you see pictures of all the judges of the supreme court, and the governors, and pictures of men in public life. You can see the same thing in a medical school. But you go into the average engineering school, and you will see pictures of machine plants, drop forge plants and things of that sort. Also in the law schools, the student has the idea that he is not going to be satisfied with anything less than a United States senatorship, or something of that sort. Your engineer has nothing like that held in front of him, and he is perfectly satisfied to go out and take the first job that he can get hold of.

Service Department

When parts are returned to the factory for credit, the metallurgist should examine them carefully to ascertain whether the material is up to the specifications, both as regards material and treatment. The part should also be examined from a mechanical standpoint to see if it has been in proper adjustment or has been subjected to unwarranted abuse and careless handling.

To accomplish all of the above, the writer realizes that perhaps time will have to be taken that is being used at the present time for purely technical instruction and this brings up the final point.

As the average entrance age is 17 or 18 years, the writer believes that this should be done in engineering schools and the courses expanded to include the following:

Factory organization,
Business Administration,
Engineering Contracts and Law,
More English including a short course in public speaking.

Prof. Goodale (chairman): Is there any discussion on this paper?

Mr. Thum: Mr. Chairman, I have listened with a great deal of interest to the various addresses this afternoon. It seems to me that the tendency which is underlying modern engineering education is going toward the longer course, four or five years and even six. Personally, I feel that such a step would be a mistake, principally because it would limit the number of students who could partake of the educational advantages of this country. It is hard enough for a great many of our good students to go for four years, but it will be very much harder to go five years, and I think that a six year course is practically out of the question.

Of course all education is good. I believe none of us would deny that a man who is educated in the liberal arts would make a better engineer than a man who merely had a high school education. I am quite sure that he would make a better engineer; in addition to that, he would make a better citizen.

Now, if the engineering schools are to teach engineering, it seems to me well that they would stick to engineering. If a man wants humanities, let him go to a school which teaches humanity. By that, I do not mean of course that absolutely no attention be given to English or public speaking, but I do think that rather than extend the course of the present four years to five or six years, in order to take up humanities, it would be very much better to examine carefully the present curriculum, and see whether some of the things which are given at present could not be well substituted by other courses.

I have traveled around more or less in the last four years, and during that time I had the honor to be a member of the faculty of the University of Cincinnati; and my experience has been that most of the metallurgical courses at present offered in this country are hybrids; they are merely slight adaptations of mining and engineering courses. Of course, there is an historical basis for that.

When I was a boy, heat treatment was practically unknown. Most of the ore smelting was done close by the mine. The modern large smelter and manufacturing plant was unknown. Things have changed in 30 years; and perhaps in 30 more years the universities will come to the conclusion that they had better do something about it. I speak advisedly because, having been a member of a university faculty, and one not so backward at that, I would like to stake the ordinary university against anything in this world when it comes to sheer inertia. They will get around to it after while, but it seems it is a long time coming.

Again reverting to the fact that metallurgical engineering is more or less the same as mining engineering, I would like to ask why the metallurist should be asked to take mining surveying, for instance, or mining engineering. The metallurgist is not particularly interested in the long haul versus the short haul method of coal mining, or the square-setting method they use for setting stakes, or the testing methods used in the iron country and so forth, and yet he in a great many cases has to take that as a prerequisite for his graduation. It merely seems to me that since there is a great demand for the humanities, it would be very well, indeed, to go after some of these so-called metallurgical courses with a sharp broad-axe, and cut out some of these things which they have had for the last few years, and which have not the remotest connection to the technical end of metallurgy as we understand it at the present time.

Of course, in order to revise and re-vamp a course of that kind, you would have to define metallurgy. That would be a difficult thing to do. But, if you agree with me that it involves the preparation of a metal from its ore, and the preparation of chemical alloys from the metals,—from such a definition of that sort, or a more perfect one, it would be comparatively easy to get a curriculum which would refer to that, and would devote the extra time which it has to such things as English, public speaking, history, economics if you will and some of the other things which are supposed to make an engineer a good citizen.

Now, it has been brought out, and I think very well, that the fundamentals should be taught rather than the specialties. No university can turn out a specialist. In the first place, they have not the equipment; they have not the teachers, the best they can do is to ground a man in the fundamentals. And I think that metallurgy should be taught very well from that standpoint. In the preparation of the metal from its ore, you have several fundamental operations, roasting, smelting and refining. The fundamentals of roasting are practically the same whether you are roasting the ore for the production of sulphuric acid as a by-product, or whether you are roasting sulphur from the iron ore, and so on down the line. There is a great deal in common in the burning of bessemer knap, copper knap and pig iron. And so when they get over into the alloys, you have physical chemistry, and physical metallurgy as a fundamental. In that connection a great deal could be done, and as far as I know, absolutely nothing is being done in this country in the teaching of the practical end of alloys, for example, how to make a brass casting that does not look like a sponge.

Then, going on, of course, you have the broad fields of heat treatment, defective coal and carburization and what not, which applies not only to steel, but to a great part of aluminum and copper alloys as well. Given, of course, a modern curriculum which applies to metallurgy, you come right back to the great question which seems to me that it is not how you teach, or why you teach, but it is the teacher himself that counts for the most. I personally am a great believer in the idea that the student gets the most value from his university training from his instructors and from his fellow students. By all odds, that was the greatest thing in my university life; and observations of other chaps since that time has only confirmed that belief. The prime thing about university life to make a good citizen, to make a good engineer, is to give him the right kind of instructors, men he can look up to; and then give him the right kind of associate, the right kind of surroundings.

Now, unfortunately,—I rather venture on this with some temerity, in view of my many good friends in the teaching profession here—unfortunately, we haven't as yet the highest grade of men teaching metallurgy. I feel that we will not get those men until some of the big business men in the steel and the copper industry, and the other metallurgical industries, suddenly realize that in view of the importance of metallurgy, the attention which they are giving to metallurgical engineering is shameful. There is no other word for it. We have tremendous foundations and endowments in medicine and law, and what-not; and yet here is a fundamental industry of our country, which enables to produce more metals and metal products than any other

country in the world, and yet we have no organized effort in the industry for the teaching of the men who are to carry that work forward. Until that time comes, until the university can properly endow the laboratories and properly endow the chairs, so that they can go out into the industry and compete with the industry for the right metallurgists and put them in the right place, I am afraid metallurgical education in this country is going to be backward.

Prof. Boylston: Mr. Chairman, there is one remark I would like to make there. Mr. Thum spoke about the course in mine surveying that we give the metallurgist. He only mentioned that so I think I ought to say something about it. I think that is one of the courses that does more to humanize the student than perhaps any other course in our school. They go down there for about four weeks, after proper class-room instruction, so that they know how to use the instruments, they climb around in the muck and they live out of doors for a month, in association with their companions and with their instructors, and they have a nice rough time of it, and they learn a good deal more than mine surveying as it is mapped out on paper. I think that is a real humanizing course; that it so in our school anyway.

Mr. Thum: There is one thing that I would like to add. One of our number just touched upon the tendency everywhere for engineering schools to require some practical experience from the men before they graduate. In our course in metallurgy, at Ohio State university, a man cannot get his degree until he has had one whole summer, at least, in practical work in this line. Then he has to come back, with a properly certified letter concerning his work from his employer; and the teacher particularly always takes another metrod of checking up on that man. In addition to that, we have inspection trips, as Prof. Boylston's slide shows you. So that there is a good deal of the practical touch in the course,—as much as can be made possible.

Prof. Upthegrove: I do not like to agree with Mr. Thum in so many things, because our work at the University of Michigan is the outgrowth of the mining course. And it is the outgrowth of the mechanical engineering course, but we have one mining engineer that we are exceedingly proud of, and that is Mr. Brush of Cleveland, who was granted the title of mining engineer from the University of Michigan; but our course does not carry many of the subjects to which Mr. Thum refers, but it rather carries a certain fundamental mechanical engineering course. We believe the metallurgists should have a foundation. It probably has not gone as far as in the metallurgical work as we should like to have it. We should like to have it include certain things along the line of which Prof. Boylston spoke. If manufacturers would only provide the necessary equipment, we would be glad to take up the work of research in the various institutions.

Our metallurgical work really starts in on the instructive basis and follows through with a certain amount of work on fabrication; and we are attempting, although not to any great extent, but just starting in along another line that Mr. Thum mentions and that is in the hope to show a man how to do some of this work in producing what you would call a finished casting. That of course is a little in the distance yet. But, that is the line along which we are really working at the University of Michigan. It is probably due to the fact we are not

connected with a mining course, to begin with, but it really is the outgrowth of mechanical engineering.

Prof. Boylston: I would like to add that in Cleveland we teach our boys how to mold and do certain other foundry operations in technical high school. We do not believe that the college grade of school should teach trades or the art of any particular metallurgical process from the point of view of art itself. We are trying to teach fundamentals also. We have not the same idea as some others as to what fundamentals consist of. We are trying to teach fundamentals, not art. That seems to be a necessity. I o not know where you can get that outside of a college course, only in the school of bitter experience. Taken by and large, our courses are planned from the standpoint of principles rather than practice.

Mr. Thum: Just a word more. I would be extremely sorry if any of the remarks I have made were taken in a purely personal way by any of the men here either against them or their institution. I tried to make them general; and the general ideas, which I so very poorly expressed, were that we yet have to approach metallurgical education as a unit itself and not as a hybrid: and second, the metallurgical industry is not supporting metallurgical education as it should.

Prof Knight: There are just a few words I neglected to say awhile ago in my few remarks that I hurriedly compiled, in regard to the work at Penn State, and that the other one is in connection with the practical work there required. We require four weeks of practical work, that is, inspection work of metallurgical plants. The way we have that arranged is, that in the junior year of the second semester, we give a course, a four hour course in the metallurgy of iron and steel. At the conclusion of the semester, we immediately take a two weeks trip, generally into the Pittsburgh district, and spend two weeks inspecting all phases of metallurgy of iron and steel from the ore as it comes to the blast furnace, and into the various finished products. Then in the senior year, in the second semester, if you will note in the catalog, if any one is particularly interested, we give a course in nonferrous inspection, and we take two weeks of nonferrous inspection. Another thing, in the school for mining engineers, we have meetings as a general rule once a month, after which time we aim to get men from the outside, either big men in the teaching profession, or men in the practical world to come in and give addresses, in order to bring the students into close contact with the actual operating of the plant.

As far as the five year course is concerned, we have the four year course given as liberally as we can; and if any one wants to, we have the Master of Science in Metallurgy. I might mention that in the four years we give the degree of Bachelor of Science in Metallurgy. The Master of Science is given at the end of the fifth year, providing they pass all examinations and requirements. The degree of Master of Science in Metallurgical Engineering is given to students who have the Bachelor's degree, and who have completed three years of work outside, and then have submitted an actual thesis showing that they have actually conducted some piece of important work and have had charge of it.

Mr. McKnight: Speaking entirely from my own very brief experience, I would say that the education of the metallurgist could be di-

vided up to include four phases, that of the fundamentals which have been spoken about, breadth, balance and co-ordination.

It is necessary to dwell long on fundamentals. It is almost axiomatic that an engineer cannot go into the higher studies unless he understands elementary chemistry and physics and mathematics.

As far as breadth is concerned, I think that the subject of specialization can be carried too far. If a man could look ahead 50 years and see that all of that time he is going to be engaged in the production of steel by the open-hearth process, eventually arriving at the position of open-hearth superintendent, at which job he would stay, it would be very easy to teach that man how to produce steel by the open-hearth process; and you could then specialize. But, when a man leaves college, he does not know whether he is going to be a heat treater, an open-hearth superintendent, or any other particular kind of work. He may change into five or six different lines of work. Therefore, I think it is very proper that the colleges should keep their course as broad as possible. It should not be carried to the extreme I was thinking of a moment ago where one of the colleges had a man who was pretty good in football, and he flunked the course in ancient history, and the professor tried to coach him through that course, but he seemed to be bent on fouling it, so that finally the professor gave it up in despair. The man had to play the next day, and the professor said "answer one question, and I will let you out." He asked him, "who dragged whom around the wall, how many times, and why?" And he could not answer the question.

The next point is balance. That is best illustrated in my opinion by a brother of mine who had graduated from a well known eastern university, and was going into the steel business; and in his senior year, he studied Italian literature, Spanish history, political economy, accounting, and field artillery. I think that is what you would call a case of very poor balance in a man's education. It seems to me that he had a very poor balance between what has been termed here the humanizing elements of the course, and the more technical elements. There is a dividing line.

The fourth point, that of co-ordination is brought to my mind because I think there are so many students who study metallurgy and get out into the world as metallurgists who have not co-ordinated the facts. As an example of that, I might take the boy who studied metallurgy at one time, one year, and studied mechanics, bricks, and materials another and studied heat treating another time. It seems to me those courses could be co-ordinated so that the man would take some standard brand of steel—not a brand of steel but some standard analysis of steel, and would heat treat that himself; would pull the test piece on the test machine, and see what physical properties were there; and then would take his metallographical sample and examine it under the microscope. In that way I am quite sure it would be more firmly fixed in his mind, and he perhaps would know them; and the properties would be all the more co-related. Instead of that, in a great many of the schools, the courses are so separated that there is no connection between the properties.

Prof. Boylston: Mr. Chairman, may I say that our so-called thesis work is planned with the idea of co-ordinating all of the previous courses.

Of course, we do not have as much time to do it as we would like to, but our men have five afternoons a week, of about three hours each, and as much extra time as they can cram in for half a year with just that purpose in mind.

I would rather they would learn how to do that, rather than get any actual results, that is, results of value for publication, or anything of that sort.

Prof. Demorest: I might add one thing along that line, and I think it is going to be very effective in our course in metallurgy, and that is running throughout the last two quarters of the senior year we have a course called "metallurgical investigations," in which the class is divided up into perhaps three sections and maybe four, depending upon the type of men we have; and each section then takes a subject, and under the direction of the instructor carries out a complete line of investigation. That is entirely different from his thesis which he has to carry on his own accord. Then the other section of the class carries out an investigation under the direct supervision of the instructors. That has been found very valuable and particularly effective in other work, and we have taken it over in metallurgy. It may be useful to others.

Mr. Wood: There is one point that has been brought up here that I want to mention, about the fifth year. It has been said that it would not be possible in many cases to send the boy to school five years, that it is hard enough to send the boy to school four years. Now, actually that does not present so much difficulty, because in a great many cases there are assistant professorships and fellowships open to students, and they make it possible for the students to stay five years, if they desire, right straight through. In a great many cases you will find this happens: That a man has graduated, and he will go out and take a position and sometimes "find himself" and then he will appreciate the fact that a fifth year would have done him a real good; and we find them drifting back, sometimes on their own expense, and sometimes, but very rarely of course, sometimes coming back on half pay from the concern they are working for. So that I think there is really a feeling for the fifth year, and there is a great deal to commend it and that the financial question is not a serious one.

Prof. Boylston: Mr. Chairman, may I say just a word on that? It seems to me it makes a difference in the fifth year whether you are going to prescribe it as a part of the required course, or whether you make the fifth year optional with those who can afford to do it. My choice would be to have an optional fifth year, and lay out an optional course for them, and allow those who have the additional time and means to take it. It is quite a different thing in the way it works out practically. We handle it in the graduate school course. In most places, it is handled through the graduate school.

Prof. Goodale (chairman): I might say, from my own experience, that our curriculum in both the mining and metallurgical engineering course, is under almost constant revision every year—I have sometimes thought too much so,—because we hardly get the curriculum on one basis in working order before we get a suggestion from some source or the other, some practical suggestion, where they think we can make it better. In that way we attempt to make the curriculum as effective

as we can, so that the men we turn out will make good in the industry. I think perhaps we are working under one condition where we feel competition that some others do not. Of course, we have two schools in Pittsburgh, the Carnegie Institute of Technology, and the University of Pittsburgh,—both schools offering courses in mining and both offering courses in metallurgy. Both schools naturally have a very keen desire along the lines of their students making records. We are very much on our toes towards that end. Every other school is probably just as much so, only they are not so closely in contact with competition as we are in Pittsburgh.

I am sure that we can go on almost indefinitely and have others outline their experiences and their ideas. I feel that I owe an apology to the speakers who have favored us so far. Most chairmen of meetings will say more in words of appreciation of the speakers than I have; but I have not done so merely to save time on the program. It seems to me that each man has brought up a great deal that is well worthy of the attention of us all.

We have a short written contribution from Hugh P. Tiemann of the Carnegie Steel company and another one from D. H. H. DeLong, of the Carpenter Steel Co.

Mr. Tiemann's Contribution to Symposium on Metallurgical Education

While the present discussion is supposed to relate to what is needed for a course in metallurgy a few remarks may be permitted calling attention to certain points essential to any kind of education. These are:

Clear thinking
Clear seeing
Clear writing
Clear speaking

The man who has not been taught to think and to see (both mentally and visually) can never get very far. A knowledge of the principles of logic is necessary in order that he may distinguish between truths and fallacies and between real facts and mere opinions or guesses. Moreover, the trained mind takes nothing for granted, but subjects any data or information to tests sufficiently rigorous to determine their reliability.

Such training will teach a man how to study. Many students are overwhelmed with the mass of facts to be assimilated. By proper methods he will learn by heart the fundamental principles around which the details will naturally and easily fall into place. It is much better to know where to find the details than to attempt to remember them all as this usually leads to endless confusion.

Clear writing and speaking enable a man to convey his thoughts to others so they can be readily grasped and without the obscurity and ambiguity that are so frequently present. A command of language is a tremendous asset not only in carrying out any personal work but also in directing the work of others and in commanding their attention and respect.

I should therefore, recommend the inclusion of ample courses in logic, observation, rhetoric, and elocution.

Coming now to what is essential in the teaching of metallurgy itself this will depend to a certain extent on what application is to be made of it. If pure metallurgy is to be followed consisting of smelting the ore, and refining, working and treating the metal, chemsitry must be the basis, since metallurgy is only one branch of applied chemistry.

Chemistry courses should cover general inorganic, analytical, applied and physical. General metallurgy including a study of heat, fuels and refractories, applied metallurgy and metallography and mechanical testing are obvious.

Courses should also be given in mathematics, including algebra (at least through quadratic equations), trigonometry, geometry and analytical geometry; mineralogy and crystallography, and mechanical drawing. A knowledge of French and German is helpful but not strictly necessary.

Sufficient laboratory work should be given to illustrate the various principles and to familiarize the student with chemical phenomena and methods of analyisis, mechanical testing, the use of the microscope, preparation of specimens, pyrometry, etc. Occasional visits should be made to modern plants manufacturing, working and treating the metal, in order to better understand what is being studied.

In my judgment the greatest stress should be laid on the underlying principles without any special effort to teach the practical details except in the case of work regularly done in a laboratory such as chemical analysis, mechanical testing and metallographic examination. The school is the place to learn theory, and the plant, after leaving the school, the place for practice.

If metallurgical engineering is in question additional subjects are necessary such as mechanical engineering, higher mathematics, through mechanics and thermo dynamics, electrical engineering, and business management. In this case the ability to design, erect and direct are needful.

Contribution By Mr. DeLong entitled:

METALLURGICAL EDUCATION

In outlining a university course which is to prepare students for a metallurgical career in industrial work it appears to the writer that two fundamental lines of training should be considered.

First—The student should be so fully equipped with the fundamentals of science, languages, mathematics and engineering that he may have readily available or can very easily secure the full benefit of past progress and experience in any branch of the metallurgical art.

Second—The student should be given such general training that he will be enabled to make the fullest use of the opportunities which may be presented to him.

The present collegiate training does well with the first of these two divisions, and there is little criticism to be offered in respect to the basic information given, with the possible exception that it is not always thoroughly absorbed by the student, and for this reason it might be well to so arrange the course that more time is spent upon the fundamental theories and principles involved and less time upon the details of specific processes involving their use. Inasmuch as the student has rarely made a decision as to the particular branch of metallurgy in which he will eventually specialize, little is gained by giving courses in specific processes during the collegiate term. This work can, however, be very profitably undertaken by employment in industrial plants during the vacation periods or by limited post graduate work in the university.

There does, however, appear in many cases to be a lack of proper training in the second of the above two divisions, namely, the ability to make fullest use of the opportunities presented.

To improve this condition, there are two particular lines of training which the writer would suggest be given greater attention during the collegiate term than is at present the case. These are as follows:

1. ECONOMICS—A question continually asked the metallurgist and which is vital to his success in commercial work is, "Can your process be operated to show a financial profit"; or "Can a process now in operation be so improved as to cut down the cost of manufacture, or to produce an articles commanding a higher sales value?" In order to properly answer this query it is necessary for the metallurgist to be informed in reference to cost accounting systems; and, further than this, he should be able to sense keenly the financial value of his work. Training in cost accounting, purchasing and selling systems and similar branches of applied economics could readily be incorporated into a metallurgical course in college and would prove invaluable to the graduate in the development of his work.

2. THE ART OF EXPRESSION—Many a valuable suggestion coming from the research department of an industrial plant has failed of adoption with subsequent loss to both the originator and to his employers because of the inability of the metallurgist to present scientific data in clear and simple terms which will appeal to the non-technical mind. While it is understood that the writing of theses is an established part of the metallurgical curriculum, it should be borne in mind that these articles are written for presentation to a superior who has an even more thorough knowledge of the subject than the investigator himself, and criticism of a thesis is often based more upon the accuracy of the data presented than upon the form or clarity of its presentation. In industrial work, on the other hand, the results of research work must frequently be presented to superiors skilled in other than the scientific details of the business involved, and it is essential for this reason that such reports be couched in terms which are readily understood by the lay mind, and that the facts be presented in a logical and convincing manner. The writer would, therefore, suggest the incorporation in the metallurgical course of a thorough training in the higher branches of English and applied methods of expression. While it is agreed that colleges at present maintain a very high standard in their entrance requirements regarding knowledge of the English language, it is believed that the study of its use in connection with scientific terms is not advanced to the proper degree during the college course itself. It is also well to make sure that the graduate is thoroughly familiar with the presentation of facts and data by approved graphic methods, that is, by the use of charts, diagrams, blueprints, etc., as these are of great aid in presenting details of intricate mathematical calculations.

The above embodies two suggestions which have occurred to the writer as a result of his contact with recent college graduates, and he trusts will prove of interest to those having charge of the outlining of collegiate courses leading to degrees in metallurgy.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION NO. 66. What method and procedure is used in brazing Stellite to carbon steel?

QUESTION NO. 67. What is the reason for the fact that a piece of steel quenched in brine will be harder than the same piece of steel would be if quenched in water, providing that the quenching temperatures and quenching medium temperatures are the same in each case?

QUESTION NO. 68. What is the correct temperature of heating for forging, a .40-.50 per cent carbon steel into automobile crankshafts?

QUESTION NO. 69. Is sulphur up to .10 per cent detrimental to the quality and physical properties of an automotive steel?

QUESTION NO. 70. Is it possible to have a specimen of steel in such a condition that it will show in any one field observed under a microscope at 100 diameters magnification, ferrite, pearlite, sorbite, troostite and cementite?

ANSWERS TO OLD QUESTIONS

QUESTION NO. 27. What is the function of the high phosphorus and the high sulphur content in the so-called automatic screw stock steel?

QUESTION 53. What is the composition of the so-called semisteel?

ANSWER. By Francis B. Foley, Bureau of Mines, Rolla, Missouri.

According to Frank E. Hall in paper presented to the spring meeting of the American Institute of Mechanical engineers semisteel was introduced to supply the need of a metal stronger than ordinary cast iron to supplement the supply of steel for war purposes. Because of its greater degree of fragmentation it was found more useful for certain types of shells. It is not steel but cast iron made in a cupola by a mixture of approximately 40 per cent of pig iron, 25 per cent steel and 35 per cent remelt scrap. In melting, limestone is used for slag making in short heats and in long heats some fluorspar is used in place of some of the limestone. Typical composition runs

graphitic carbon 2.40 per cent, combined carbon 0.60 per cent, silicon 1.25 per cent, manganese. 70 per cent, phosphorus 0.10 per cent, sulphur 0.11 per cent. Hall recommends that the silicon plus total carbon be not less than 4 per cent and that the best results seem to lie between 4 and 4.40 per cent for the total of these two elements. The French specifications, revised, stipulate a tensile strength of not less than 32,000 pounds per square inch, and a hardness not less than that represented by a 4.6 millimeter impression on a Brinell machine at 3000 kilogram load. Under a test requiring the dropping of a 25-pound weight vertically from a height of 12 inches at the start and then repeating, each time raising the weight ½ inch, the specimen, 1½ inches square by 8 inches long shall not fail under less than an 18-inch fall of the weight.

QUESTION NO. 56. Which is the best method of producing large forgings, pressing or hammering?

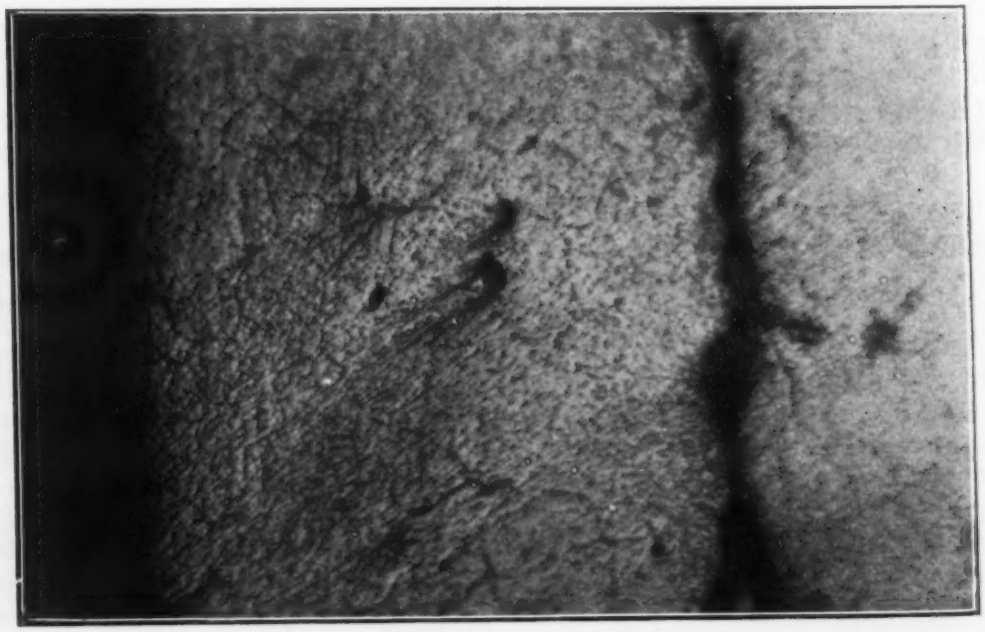
QUESTION NO. 57. Does repeated heating just above the critical range with subsequent quenching, of a steel specimen injure its physical properties?

QUESTION NO. 59. Is a sulphur content of 0.067 per cent detrimental to the proper carburizing of a low carbon steel having a low manganese and phosphorus content?

QUESTION 61. What are the causes of scaling or spalling of the case of a carburized steel?

ANSWER. By James Sorenson, metallurgical engineer with the Four Wheel Drive Auto Co., Clintonville, Wis.

Scaling or spalling of a carburized steel is usually caused by the extreme



surface of the case having a considerable amount of free cementite present. The accompanying photomicrograph shows the structure of a carburized bearing race which failed in service. This specimen was etched in sodium picrate which naturally would make the cementite veins appear black. It is clearly seen in this case that the plane of weakness is right next to the hypereutectoid portion of the case, and had this free cementite been eliminated either through suitable heat treatment or preferably prevented in the first place by proper carburization, no doubt, this particular part would have stood up over a much longer period of service. If the carburized case has a carbon content of from .90 to 1.10 per cent, very little trouble will be experienced with scaling or spalling of the case, as free cementite is not very apt to form if the carbon is kept within the above mentioned limits.

It is also very important that the distribution of carbon from the extreme surface of the case to the hypo-eutectoid core should at no place show any indication of a great variation in carbon content, but should rather exhibit a gradual change from the extreme surface of the case to the core. This can be accomplished by using a comparatively slow and uniform carburizing material and at a temperature slightly above the upper AC-3 point of the steel.

QUESTION NO. 62. What is the difference between annealing and normalizing steel?

QUESTION NO. 63. What causes the surface of a carburized steel to become pitted as a result of carburizing?

ANSWER. Pitting of the surface of carburized parts is frequently due to the condition of the steel. Sometimes, where no machining is done on cold-rolled steel, or tubing, the surface shows, after carburizing, a mass of very small pit-marks. These are caused by small particles of scale rolled into the surface which are loosened and drop out when the metal is heated and quenched.

When parts that have been machined show pitted surfaces the fault is probably in the carburizer. Sulphur in the carburizer with a little moisture will produce the condition.

QUESTION NO. 64. To what extent can the deep etching of specimens of steel be applied to routine examination of incoming material?

QUESTION NO. 65. What is the relation between the elastic tensile strength and the elastic compressive strength in ductile steels?

ANSWER. The elastic strength in tension and in compression for ductile steels is usually considered to be the same. This assumption is sufficiently accurate for many purposes. In the problems of combined stress and in built-up compression members, however, it is important to know accurately the relation between the elastic tensile and compressive strengths and particularly to know how the strengths are affected by mechanical treatment of the steel such as the amount of working during the rolling process. Data available

(Continued on Page 588)

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

SERVICE FOR MEMBERS

The Library Bureau of the American Society for Steel Treating is operated to give to the members quickly, reliably and at the minimum expense the following service:

1. A complete copy of the magazine article referred to in any periodical you may be reading.
2. A translation of foreign articles that would help you with your work.
3. A list of references to books and articles on any metallurgical subject.
4. Informing the members of new articles of interest to them as an engineer.

The Library Bureau makes the entire field of literature available to every member, distance is eliminated, for it will copy the desired information and send it to you. It also helps the busy man by supplying information without any expenditure of his time. The charge for this personal work is merely its cost.

The Library Service does not obtain any profit from the work, but does this to make the information contained in the large libraries with which it has connection available to every member. The rates are as follows:

Photo Print Copies of articles, drawings, etc., 25c per 10 x 14-inch sheets.
Searches, abstracts, etc., $2.00 an hour.
Translations, $6.00 per thousand words for French of German; $7.50 and upward for other languages.
Reference card service, giving reference to current magazine articles, $10.00 a year in advance, and 5c for each card mailed.

Members desiring to avail themselves of this service should address Library Bureau, American Society for Steel Treating, 4600 Prospect Ave., Cleveland, Ohio.

SECTIONAL BLANKING AND PIERCING DIES. By Fred R. Daniels in January 1923 *Machinery*.

The above article gives the advantages of sectional dies and the methods used in their construction. It states that sectional dies are used extensively in the production of armature laminations for electric motors and generators, and are also applicable to the manufacture of other classes of stampings containing a large number of perforations. The only essential difference in design between the sectional lamination die and the solid die is that the punch holes in the sectional die are formed by sections arranged radially and accurately fitted and assembled on a plate. These assembled sections form the lower die, as in sub-press construction. The article also describes the methods used in manufacturing sectional blanking and piercing dies.

PRACTICAL NOTES ON THE HEAT TREATMENT OF HIGH SPEED STEEL. By H. K. Ogilvie, in December 1922 *Forging and Heat Treating.*

The above notes were taken from a paper read before the Iron and Steel Institute (British) September, 1922.

The above points out the importance of careful heat treatment of high-speed tools; determination of the quenching and drawing temperatures; mechanical considerations; and the importance of the use of the microscope and pyrometer.

THE DETERMINATION OF SULPHUR BY COMBUSTION IN A STREAM OF OXYGEN. By A. Vita, Chief Chemist in Friendenshutte O. S. In December 1922 *Forging and Heat Treating.*

The above was translated from *Stahl und Eisen,* July 15, 1922. The analytical determination of sulphur in pig iron, steels, ores, slags and fuels by combustion in a stream of oxygen is described in detail in the article. Special cases and limitations are also discussed.

METHODS OF COLD HEADING CAP SCREWS. By John B. Frederick. In December 1922 *Forging and Heat Treating.*

The author presents two methods for cold heading, a correct and an incorrect, and by an analysis shows the truth of the one and the fallacy of the other. The data accompanying this article is original and shows the effort of years of experience in cold heading and wire working, aided by a fundamental knowledge of metallography.

POWER REQUIRED FOR CUTTING METAL. By Fred A. Parsons, Chief Engineer, Kempsmith Milling Machine Co., Milwaukee, Wisconsin. In *Mechanical Engineering,* Vol. 45, No. 1, January, 1923.

This paper gives the results of an investigation extending over a period of more than ten years, the purpose of which has been to determine the fundamental laws governing milling, turning, planing, and drilling operations on the various metals and alloys used in machine construction. A large number of tests have been made on milling machines constructed by the firm with which the author is connected.

The author's results are presented in the shape of formulas and tables by means of which the power required to machine metal in any given case may be calculated, and an example of their use is worked out in detail.

THE SEPARATION AND DETERMINATION OF SODIUM AND LITHIUM BY PRECIPITATION FROM ALCOHOLIC PERCHLORATE SOLUTION. By H. H. Willard and G. Frederick Smith. In *Journal* of the American Chemical Society, Vol. 44, No. 12, December 1922.

The work done in connection with this article was suggested by H. H. Willard and the preliminary work was carried out at the University of Michigan. The final work was done at the University of Illinois.

In this article a method is described for the separation of sodium and lithium based upon the precipitation of sodium chloride from a solution of the perchlorates in anhydrous n-butyl alcohol by the addition of an alcoholic solution of hydrogen chloride. Conditions affecting the accuracy of the process were studied. A table is given showing the density and composition of solutions of hydrogen chloride in butyl alcohol. Test analyses show that one separation gives accurate results even in the presence of large amounts of lithium.

PROMPT AND ACCURATE CARBON DETERMINATIONS. By Thomas Hill, metallurgist, Best Steel Casting Company. In *Western Machinery World*, January, 1923.

In the above article is given a description of the methods and apparatus found satisfactory under difficult steel foundry conditions.

THE PREPARATION AND PROPERTIES OF PURE IRON ALLOYS: II. MAGNETIC PROPERTIES OF IRON-CARBON ALLOYS AS AFFECTED BY HEAT TREATMENT AND CARBN CONTENT. By W. L. Cheney.

The results of the investigations showed that the hardened alloys when drawn back to successively higher temperatures showed certain magnetic transformations; while the annealed alloys showed a decided change in the steepness of the curve and hence a change in the permeability, with a change in the percentage of carbon content.

PREPARATION AND PROPERTIES OF PURE IRON ALLOYS: III. THE EFFECT OF MANGANESE ON THE STRUCTURE OF ALLOYS OF THE IRON-CARBON SYSTEM. By Henry S. Rawdon and Frederick Sillers, Jr. *Scientific Papers* of the Bureau of Standards No. 464.

This article points out that in the manufacture of steel, manganese is one of the most important materials. The effect of manganese upon pearlite is to place upon it a very fine sorbitic structure. The article also states that a decided decrease in grain-size was found in the normalized alloys of high manganese contents.

GASES IN METALS. 1. THE DETERMINATION OF COMBINED NITROGEN IN IRON AND STEEL AND THE CHANGE IN FORM OF NITROGEN BY HEAT TREATMENT. By Louis Jordan and F. E. Swindells. *Scientific Papers* of the Bureau of Standards No. 457.

This article states that it has been found that the only form of nitrogen determined in iron or steel by the acid-solution method is that which is present as combined nitrogen, which probably exists as nitrides of iron or minor parts of manganese or aluminum.

It has also been found that the amount of nitrogen as determined by the acid-solution has been increased by the heat treatment of certain steels.

DIES FOR DIE-CASTINGS. By A. G. Carman, Chief Metallurgist Franklin Die-Casting Corporation, Syracuse, N. Y. In January 1923 *Machinery*.

The above article gives specific examples of the design and construction of dies for making die-castings of the more intricate types.

ELECTRICALLY HEATED INDUSTRIAL FURNACES. By W. Trinks. In December 1922 *Forging and Heat Treating*.

The above article compares the efficiency of electrically-heated and combustion type furnaces. It gives the design of the heating elements and supports as well as the advantages and disadvantages of various types of construction.

Reviews of Recent Patents

1,430,438. Electric Forging and Heat-Treating Furnace. Frederick G. Dawson, Detroit, Mich.

The above invention relates to an electric furnace comprising a heating chamber, a common electrode within said heating chamber, a plurality of other electrodes extending into the chamber and bearing upon a surface of the common electrode, the other electrodes bearing on the common electrode, by reason of their weight, and means for adjusting the pressure between the common electrode and the other electrodes.

1,430,971. Method of and Means for Reducing Ores in Electric Blast Furnaces. Edwin Fornander, Sandviken, Sweden.

A method of reducing ores in an electric blast furnace having a reducing shaft and a laterally enlarged melting room at the lower end of said shaft, which consists in charging ore, limestone and analogous substances at the top of said shaft, which mass will descend through the shaft and collect in the melting room with free surfaces of slope, supplying reducing material directly into said melting room in such a way as to cause said reducing material to form a covering layer on said surfaces of slope while leaving a free space between itself and the lid of the melting room, and removing part of the gases formed in the shaft and returning said part directly to the melting room in such a way as to cause the gas to pass through the layer of reducing material therein.

1,430,987. Electric Furnace. Edward A. Hanff, Pittsburgh, Pa., assignor to Pittsburgh Engineering Works, Pittsburgh, Pa., a corporation of Pennsylvania.

The combination with an electric furnace having a bottom susceptible of conducting electricity and an arcing electrode of a transformer having a secondary winding provided with taps, a connection between one end of said winding and said furnace bottom, a switch for selectively connecting said electrode to any desired one of said taps, and an adjustable reactance in circuit with said electrode.

1,431,621. Method of Manufacturing Steel. Jay C. Beneker, Seattle, Washington, assignor of one-third to Frederick F. McIntosh, Glen Osborne, Pa., and one-third to William B. Skinkle, Coraopolis, Pa.

The method of manufacturing steel containing not more than about .35 per cent carbon and not less than about 1.00 per cent manganese, which consists in blanketing a bath of steel with a slag high in manganese oxides, introducing a silico-manganese alloy in such bath, and eliminating silicon by its reducing action on the manganese oxides of the slag.

1,431,680. Hardening of Thin Steel Sheets. Neil P. Petersen, Montreal, Quebec, Canada, assignor to Gillette Safety Razor Company.

The above relates to an improvement in the method of hardening perforated articles of thin sheet steel by heating and subsequently chilling a stack in which

such articles are interleaved with sheets of high heat conductivity as compared with steel, characterized by the employment of sheets each having an internal opening of such contour as to provide, in connection with the perforations in said articles, an open space within the stack to which the chilling medium has access and in which limited portions of the articles are exposed to direct contact with said medium.

1,433,700. Electric Tool-Tempering Furnace. Ora A. Colby, Irwin, Pa., assignor to Westinghouse Electric Company.

In an electric furnace, the combination with a chamber and a concave roof for said chamber, of a plurality of resistors comprising solid blocks of refractory electrical-conducting material of rectangular cross-section, one of the larger faces of said blocks being so located as to radiate heat against said concave roof, a plurality of hoppers at the rear of said furnace opposite the rear ends of said resistor blocks, a hopper at the front of said furnace opposite the front ends of said resistor blocks, solid terminal electrodes in said hoppers at the rear of said furnace and a mass of electrical-conducting granular material in said rear hoppers interposed between said electrodes and said resistors and adapted to conduct the current there between and to prevent overheating of said electrodes, and a mass of electrical conducting granular material in said front hopper adapted to conduct current between said resistors.

1,434,047. Method of Uniting Hard Steel Alloys to Softer Steel Bars. Jean Hubert Louis De Bats, Zelienople, Pa., assignor, by mesne assignments, to Anatmos Metals and Furnace Corporation, New York City.

The above relates to a method of uniting high-speed steel to a tough steel body, consisting in coating a portion of the surface of the tough steel piece with a suitable brazing metal, placing said piece in a metal mold with a coated surface spaced from the mold wall, and then pouring molten high-speed steel into said space and against the mold, whereby the tough steel body has united thereto a portion of high-speed steel in its cast chilled condition.

1,434,082. Die Shaper. Ernst Bossert. Cincinnati, Ohio.

A die shaper consisting of a frame, a drive shaft journalled in the frame at its top, an intermediate shaft journalled in the frame beneath the drive shaft, a guide plate beneath the drive shaft pivotally mounted at its upper end for forward and backward movement of its lower end, a toggle connected with the plate for effecting swinging movement thereof when the toggle is operated, a tool-carrying side plate reciprocally mounted on the guide plate, an eccentric mounted on the drive shaft, means connecting the eccentric and slide plate for causing reciprocation of the plate when the drive shaft is rotated, and means operatively connected with the intermediate shaft for causing operation of the toggle.

1,443,631. Machine for Cleaning Scale from Annealed Steel. Ralph N. Logan, Philadelphia, Pa.

In a machine of the character stated, the combination of a frame adapted to be reciprocated, supporting means therefor, including a pneumatic counter-balancing means, a source of compressed air for making the pneumatic counter-balancing means effective, and mechanical power devices for reciprocating the frame while pneumatically counterbalanced.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Tuesday
Bridgeport—Thursday between 20th and end of month
Chicago—Second Thursday
Cincinnati—Second Thursday
Cleveland—Fourth Friday, Cleveland Engineering Society Rooms, Hotel Winton; meeting at 8:00 p. m.
Detroit—Second and fourth Monday. Detroit Board of Commerce.
Hartford—Friday nearest 10th of month
Indianapolis—Second Monday
Lehigh Valley—No regular night
New Haven—Third Friday
New York—Third Wednesday
Philadelphia—Last Friday
Pittsburgh—First Tuesday
Providence—No regular night. Nov. 10th, Dec. 12th.
Schenectady—Third Tuesday
Springfield—Third Friday
South Bend—Second Wednesday
St. Louis—Third Monday
Syracuse—No regular night
Tri City—Thursday
Washington—Third Friday
Rockford—Second Friday following the second Thursday

MEMBERSHIP AND ATTENDANCE CONTEST

The following arrangement of the chapters shows the percentage of increase of new members based on the number of members each chapter had on September 1st, 1922. While practically all of the chapters have shown an increase in membership over that given in the last monthly letter, those chapters printed in CAPS have passed other chapters.

The percentage of increase in membership is as follows:

	Per Cent		Per Cent		Per Cent
1. Detroit	52.0	10. BUFFALO	20.0	19. Washington	10.0
2. SOUTH BEND	40.0	11. New York	16.7	20. St. Louis	9.6
3. North West	37.0	12. Cleveland	12.8	21. Pittsburgh	9.4
4. BOSTON	30.4	13. HARTFORD	12.2	22. New Haven	9.1
5. Milwaukee	25.4	14. Chicago	11.3	23. Cincinnati	9.0
6. PHILADELPHIA	25.2	15. SYRACUSE	10.9	24. Worcester	7.2
7. L'H'GH VALLEY	25.0	16. INDPLS.	10.7	25. Toronto	3.6
8. Schenectady	23.5	17. Rockford	10.4	26. Providence	0
9. Tri City	20.8	18. SPRINGFIELD	10.3	27. Rochester	0

Attendance at December Meetings

Only 17 chapters have reported the attendance at their December meetings, consequently only that number is listed below.

The reason for the small number of chapters reporting their attendance is probably due to the fact that many regular meeting nights came during the Christmas holidays and consequently the meeting was abandoned or postponed to the early part of January.

In this connection it might be pointed out that the report of attendance for 6 meetings is necessary in order to qualify in the final reckoning of the standings of the chapters in this contest.

Providence had the largest percentage of members present at the December meeting, the percentage of attendance being 62.2 per cent; the second largest percentage of attendance, 54.5 per cent, was shown by South Bend.

The following gives the percentage of attendance for those chapters reporting:

	Per Cent		Per Cent
1. Providence	62.6	10. Cincinnati	29.5
2. South Bend	54.5	11. St. Louis	28.0
3. Syracuse	43.6	12. Detroit	27.3
4. Washington	41.5	13. Chicago	24.7
5. Hartford	36.6	14. Milwaukee	23.0
6. Tri City	34.8	15. Cleveland	22.4
7. North West	32.8	16. New York	16.8
8. Springfield	32.4	17. Pittsburgh	16.3
9. New Haven	31.3		

Standing In The Contest

In order to determine the standing of each chapter in the contest it is necessary to add the percentage of increase in members and the percentage of attendance at the December meeting and divide by 2 inasmuch as each counts as 50 per cent in determining the standings of the chapters.

On this basis we find that the following is the standing of the Chapters on January 1st in the Membership and Attendance Contest:

	Per Cent		Per Cent
1. South Bend	47.8	10. Springfield	21.3
2. Detroit	39.7	11. New Haven	20.2
3. North West	34.9	12. Cincinnati	19.3
4. Providence	31.1	13. St. Louis	18.8
5. Tri City	27.8	14. Chicago	18.0
6. Syracuse	27.2	15. Cleveland	17.1
7. Washington	25.8	16. New York	16.8
8. Hartford	24.4	17. Pittsburgh	12.9
9. Milwaukee	24.0		

Chapters not ranking high at this report should not be discouraged inasmuch as this contest will cover a period up to and including your June meeting and there is much opportunity for chapters not even represented on this list to make very rapid strides in reaching the top.

New Members

There were 86 new members added to the list last month which shows a gain over that for November when 70 new members were added to the Society. It is indeed a very fine showing and judging from the number of applications that are in the office but for which remittance has not yet been

received, the gain for January will probably be larger than for the month of December.

Based on the number of members in each chapter, the following table shows the standing of the 27 chapters of the Society. Detroit is still the largest chapter, keeping a lead of about 50 members over its nearest competitor, Chicago.

Those chapters printed in caps have advanced their position over that occupied in the December report, while those in italics have a lower position. The standing is as follows:

1. Detroit
2. Chicago
3. Pittsburgh
4. Philadelphia
5. Cleveland
6. New York
7. Hartford
8. Milwaukee
9. Boston
10. Lehigh Valley
11. *North West
12. *Syracuse
13. Worcester
14. *Indianapolis
15. *St. Louis
16. Rockford
17. Tri City
18. BUFFALO
19. WASHINGTON
20. **Cincinnati*
21. *Schenectady
22. Springfield
23. Providence
24. SOUTH BEND
25. *New Haven*
26. Toronto
27. Rochester

(*)—Tied

BOSTON CHAPTER

The Boston Chapter of the American Society for Steel Treating held its January meeting on Tuesday evening, the 23rd, at 6:30 p. m., at the Worthington Pump and Machinery Corporation's Blake & Knowles Works, 265 Third St., East Cambridge.

The meeting was preceded by a dinner served in the shop cafeteria of the plant at 6:30 p. m.

The speaker for this meeting was W. J. Kunkel of the forge department of the Blake & Knowles works, who gave a very capable paper, entitled "Forgings." Following Mr. Kunkel's paper, a short talk was given on the Worthington Diesel Engine built at the works of the Worthington Pump and Machinery Corporation and one of these engines was on exhibition and in operation.

Following this program the forge department of the plant was open for inspection. The department was in operation and a demonstration of the manufacture of crankshafts and other engine forgings, as well as ring forgings, forgings of Monel metal and Tobin bronze was witnessed by all. A demonstration showing the advantages of the acetylene cutting torch in forge shop practice was performed for the visiting members.

This meeting was very well attended and proved to be a decided success.

The February meeting is scheduled to be held in the Boston plant of the Edison Electric Illuminating Company. The subject for this meeting will be "Electricity and its Application to Heat Treating Furnaces." Demonstrations are being arranged and a real live meeting is planned.

CHICAGO CHAPTER

On January 12th the Chicago chapter of the Society held its regular monthly meeting at 8 p. m. in the Chicago City Club rooms, corner of Jackson Blvd., and Plymouth Court.

James P. Gill, metallurgist of the Vanadium-Alloys Steel Co. presented his paper entitled "The Tempering of Tool Steels."

The printed circular announcement of this meeting anticipated to some degree the details of Mr. Gill's paper and commented as follows:

"The title sounds very simple. It would seem to indicate that all that is necessary to do to temper a piece of tool steel is to heat it up until it shows a color comparable to that of a bale of rye straw grown on George McNallys' farm, which is located on the N. E. ¼ of the S. W. ½ of Section 23 north range 13, County of Whistleville, North Dakota, and throw it in a tub of brine of a sufficient density to float one Idaho potato before being baked and containing one piece of good grade all wool piano felt so as to prevent tool loosing temper when it strikes bottom of tub.

"Mr. Gill will make the definite statement that 'them days are gone forever.'

"He is going to prove to us that there is no connection between the tempering of a piece of tool steel and a bale of straw or even a flock of pigeons. He will even go so far as to say that a red-headed boy can temper tool steel but that it is not essential that he be red-headed. This must be so because Mr. Gill hasn't a red hair in his head. He also will say that goats have nothing to do wtih the heat treatment of tool steels even though they be fed on green ferns grown on the hillside among the tall and stately cypress trees.

"From the above statements it can be seen that Mr. Gill has some real dope for the members. If your committee ever finds another goat tied up in the corner of a Chicago hardening room, they will know that the members from that plant failed to attend the January meeting."

Although Mr. Gill did not follow the outline as given in the announcement, he did present a very capable, instructive and interesting paper on the subject of hardening and tempering tool steeels. It will undoubtedly be recalled that Mr. Gill presented a very capable paper at the Indianapolis annual convention of the society, which won for him the silver medal of the society. He is a recognized authority on the metallurgy and metallography of tool steel.

The usual get-together dinner was served at 6:30 p. m. in the dining room of the Chicago City Club. A very good turn-out was had at both the dinner and the meeting following.

Announcement has recently been made that Harry Blumberg, former secretary and treasurer of the Chicago chapter of the society has accepted a very responsible position with the A. O. Smith Corp. of Milwaukee, Wis. In making this change, Mr. Blumberg has resigned the office of secretary and treasurer of the Chicago chapter which he has so capably filled for the past three years.

Arthur G. Henry, special representative of the Vanadium-Alloys Steel Co., has been elected to succeed Mr. Blumberg as secretary and treasurer of the chapter.

CINCINNATI CHAPTER

The regular monthly meeting of the Cincinnati chapter was held Thursday evening, January 11th, at 8 p. m., in the Ohio Mechanics Institute rooms, Canal and Walnut Sts. The program for this meeting consisted of a paper by W. R. Klinkicht, assistant engineer of tests of the Pollak Steel Co., entitled the "Forging and Heat Treating of Large Sections," illustrated with lantern slides.

Mr. Klinkicht, who is an authority on the subject of forgings and heat

treating of large sections presented a very interesting and instructive paper, outlining in detail the processes of the manufacture of heavy forgings and their subsequent heat treatment.

Following the presentation of this paper Mr. Klinkicht answered many questions which were put to him by members and guests present.

This meeting was well attended and proved to be exceedingly interesting and instructive to all those who had the good fortune of attending.

Cleveland Chapter

The Cleveland chapter of the American Society for Steel Treating held its regular January monthly meeting on Friday evening, the twenty-sixth in the rooms of the Cleveland Engineering society, Hotel Winton. The program for this meeting was an illustrated paper by H. J. French, physicist of the Bureau of Standards entitled "Some Factors Affecting the Heat Treatment of Steel."

Mr. French presented his paper in a very capable and interesting way and brought out many points of interest and value to heat treaters. Following this paper a rather lengthy and interesting discussion on the practical aspect of the heat treatment of steel was held and many points of interest and value were brought out.

The usual get-together dinner was served at 6:30 p. m. in the English room of the Hotel Winton.

DETROIT CHAPTER

The Detroit chapter of the society held its first January meeting on the fifteenth of the month in the rooms of the Detroit Board of Commerce, at which time R. T. Herdegen of the Dominion Forge company read a very capable paper on "Forging Practice for Automobile Parts."

Mr. Hergegen's paper brought out many points of interest and following his paper a very lively and interesting discussion was held.

The second January meeting of the Detroit chapter was held Monday evening Jan. 22 at 8 p. m. in the rooms of the Detroit Board of Commerce and was preceded by a get-together dinner, served at 6 p. m.

The speaker for this meeting was Karl Herrmann, engineer of the Studebaker corporation, who gave a very capable paper on "Gears and their Relation to the Automotive Industry." This paper was a continuation of Mr. Herrmann's paper which was delivered last fall at the production meeting of the Society of Automotive Engineers and proved to be a very interesting paper, especially to automobile engineers and to heat treaters.

A very lively discussion followed the presentation of Mr. Herrmann's paper and many valuable points pertaining to the heat treatment of gears were brought out in this discussion.

HARTFORD CHAPTER

On Friday evening, January 12th, the Hartford chapter of the American Society for Steel Treating held its regular monthly meeting in the assembly hall of the Hartford Electric Light Co., Pearl St., Hartford, Conn.

The program for this meeting was a paper presented by E. E. Thum, associate editor of *Chemical and Metallurgical Engineering*, entitled "Educating the Metallurgist and the Management."

Mr. Thum being in close touch with the current developments in metallurgy and heat treatment of steel through his connection with the *Chemical and Metallurgical Engineering* publication is particularly fitted to discuss the problem of heat treatment from the viewpoint outlined in the title of his paper.

Mr. Thum's paper proved to be exceedingly interesting and brought out many points, showing some of the fallacies which are prevalent in the handling of metallurgical problems and in the handling of men to carry out the details of these metallurgical problems in the various plants.

Mr. W. H. Eisenman, National Secretary of the Society, was a guest of the Hartford chapter at this meeting and gave a short talk on several matters of interest to both the National Society and the local chapter.

This meeting was well attended and proved to be of considerable interest to all who had the privilege of being there.

INDIANAPOLIS CHAPTER

The regular January meeting of the Indianapolis Chapter was omitted for the month, due to the fact that the class in heat treating was commenced January 8th, and it was felt that the regular January meeting was not needed this year.

The next regular meeting of the Chapter will be held on February 13th at which time the subject of "The Open Hearth Practice of Refining Steel" will be discussed.

A great deal of enthusiasm for the new course in heat treating has been shown by the members of the Indianapolis Chapter, and this feature of the chapter's activities will undoubtedly prove to be a decided success.

LEHIGH VALLEY CHAPTER

The Lehigh Valley Chapter of the American Society for Steel Treating held a joint meeting with the Engineers Club of the Lehigh Valley on Friday evening, January 19th at 8 p. m.

The speaker for this meeting was Dr. Richard Moldenke, consulting metallurgist. The subject of his paper was "Cast Iron from the Standpoint of the Engineer." His paper was a most interesting one, and contained many interesting anecdotes from the wide experiences and travel that Dr. Moldenke has enjoyed. He is one of the authorities on the subject of cast iron as well as malleable iron, having been associated with the Foundrymen's Association as well as an honorary member of numerous other scientific organizations. He is the author of numerous papers and books on special researches on malleable iron and cast iron.

This meeting was very well attended and proved to be interesting and instructive to all.

Prior to the regular meeting the usual get-together dinner was served at 6:30 p. m. in the Hotel Bethlehem.

MILWAUKEE CHAPTER

On Wednesday evening, January 17th, 1923, the Milwaukee Chapter of the American Society for Steel Treating held its regular January meeting in the rooms of the Blatz Hotel.

The usual get-together dinner was served at 6:45 p. m. to a goodly number of members and guests.

The program for this meeting was a paper by James P. Gill, Metallurgist of the Vanadium Alloys Steel Company, entitled "The Tempering of Tool Steels."

Mr. Gill handled his subject in a very capable way, and brought out many points of interest in the hardening and tempering of tools.

The speaker has had wide experience and training in the metallurgy of tool steels, and handled his subject in a most capable manner.

NEW HAVEN CHAPTER

On Friday evening, Jan. 19 the New Haven chapter of the American Society for Steel Treating held its regular monthly meeting in the assembly room of the New Haven Gas Light company, 70 Crown St. New Haven, Conn.

V. E. Hillman, metallurgist of the Crompton and Knowles Loom Works, Worcester, Mass., presented his paper entitled "The Effect of Cold Work on Steel." This paper was illustrated with stereoptican slides and discussed the influence of the heat treatment on cold drawn, cold rolled and cold upset steel.

This paper also discussed the effect of cold working upon the grain size of the steel prior to heat treatment.

Following the paper of the evening an informal smoker was held at which time John Stevenson entertained the assemblage in his usual jovial manner.

NEW YORK CHAPTER

The New York chapter of the American Society for Steel Treating held its January meeting in the assembly room of the Merchants association of New York, ninth floor the Woolworth building, Jan. 17 at 8:15 p. m.

Frank H. Starkey of Hartford, Conn., was the speaker of the evening. His paper was entitled "The Spark Test Method for Testing Steel."

This paper proved to be a very interesting subject and was very capably illustrated both by blackboard sketches and by actual demonstrations on a grinding wheel. The speaker demonstrated the characteristic sparks for many of the different steels and the application of the spark test method for the identification of steels in actual practice.

In accordance with the request in the announcement of this meeting, many members brought specimens of steels for identification by the speaker in using the spark test method of analysis.

The usual get-together dinner was served in the Post Keller restaurant at 6:30 p. m. which is located in the Woolworth building.

NORTH WEST CHAPTER

The North West chapter of the Society held its regular December meeting in the Manufacturers Club Rooms, 200 Builders Exchange, Minneapolis, Minn.

The subject for this meeting was entitled "A Model Heat Treating Plant" and was open to the discussion of all members of the chapter.

The Ideal Manufacturing Co. of Minneapolis, manufacturers of automobiles, having called upon the members of the North West Chapter for their advice in the layout and equipment of its heat treating plant, as well

as the methods and practice to be used in heat treating the various parts of its automobile, have their construction work well under way.

The tentative plans prepared by Hans J. Meyer, the consulting engineer, retained by the Company, provide for a one-story building, 100 x 400 feet, which is estimated to cost, including the equipment, $400,000.

W. E. Johnston has been appointed chairman of the chapter's committee to study these questions and to report its recommendations. The committee presented its preliminary conclusions for discussion at this meeting. The Committee realizing that it needs the advice and counsel of all the members of the Chapter, welcomes any criticisms or suggestions they care to make. This meeting was devoted largely to a discussion of the layout and equipment of the plant.

The North West chapter of the society held its regular monthly meeting Jan. 16 at 7:30 p. m. in the Manufacturers club of Minneapolis, 200 Builders Exchange building.

The program for this meeting was a paper presented by James P. Gill of the Vanadium-Alloys Steel Co., Latrobe, Pa., entitled "The Tempering of Alloy Tool Steels."

Mr. Gill, who is a very capable metallurgist, is an authority upon the subject of tool steel and presented many practical thoughts in outlining his experiences with the problems that men had in the hardening of tools. His paper was well illustrated with lantern slides and proved to be exceedingly interesting to all those who had the privilege of hearing him.

A very interesting and helpful discussion followed Mr. Gill's paper.

PHILADELPHIA CHAPTER

The Philadelphia chapter of the American Society for Steel Treating held its January meeting Friday evening, January 5th, at 8:15 p. m., in the Engineers Club, 1317 Spruce St., Philadelphia.

The usual get-together dinner was served at 6:45 p m. in the club rooms of the Engineers Club.

The program for this meeting consisted of two papers, the first entitled "Case Hardening" by C. B. Callomon, metallurgical engineer with the Driver-Harris Co., Harrison, N. J., who presented a very capable paper on carburizing and carburizing containers. This paper developed considerable discussion on the subject of carburizing and proved to be of extreme interest to the members and guests present.

Following Mr. Callomon's paper E. E. Thum, associate editor of *Chemical and Metallurgical Engineering*, presented his paper entitled "Mutual Education of the Metallurgist and Management."

Mr. Thum developed numerous excellent thoughts pertaining to the mutual education of both the metallurgist and the executive.

The chapter was honored by the presence of the National Secretary, W. H. Eisenman, who gave a brief talk pertaining to matters of interest to the National Society and the local chapter.

The meeting was very well attended, about 45 being present at the dinner, which was served preceding the meeting, and about 200 members and guests were present for the meeting proper.

PITTSBURGH CHAPTER

The regular monthly meeting of the Pittsburgh chapter of the American Society for Steel Treating was held on January 2nd, 1923, in the meeting rooms of the Chatham Hotel, Pittsburgh, Pa.

Professor W. Trinks, head of the Department of Mechanical Engineering, Carnegie Institute of Technology, gave an informal talk on the automatic control of industrial furnaces discussing in detail various systems which have been developed during the past year, particularly during 1922.

Professtor Trinks' discussion covered both gas and oil and electrically-fired furnaces.

This paper proved to be exceedingly interesting and instructive to those who had the privilege of hearing it.

Following this paper Mr. M. Homi, metallurgist for the Tata Iron & Steel Co., Bombay, India, discussed every particular development of that company, and predicted for the steel industry in India a very promising future, particularly as ore, coal and coke and limestone can be secured within a radius of 200 miles and the native labor is very cheap. He stated that a good grade of pig iron is being produced for $5.00 per ton.

This meeting was well attended and proved to be exceedingly instructive and interesting to all.

The usual get-together dinner was served at 6:30 p. m. in the dining room of the Chatham Hotel.

RHODE ISLAND CHAPTER

The January meeting of the Rhode Island chapter was held in the new home of the Providence Engineering society at 44 Washington street, Providence, R. I., Jan. 12, 1923.

Chairman, Franklin opened the meeting by introducing Professor Hall of the engineering department of Brown university. Professor Hall is president of the Providence Engineering society and gave a short address of welcome to the steel treaters and invited them to use the new headquarters of the engineering society, and likewise he explained the benefits of membership in the engineering society.

Mr. Franklin introduced E. C. McCormick, assistant metallurgist of the Crompton Knowles Loom Works, Worcester, Mass., who presented a paper entitled "The Use and Abuse of Pyrometers."

Mr. McCormick first reviewed the history of pyrometers and then went into the details of the instruments, explaining how the metals in the fire end produced the electric current and how this current is transmitted and the strength of it measured by the galvanometer. He explained the manufacture of the parts going to make up a pyrometer and pictured in detail on the blackboard, the inside working mechanism of a millivolt-meter. Mr. McCormick had a pyrometer with him which was used to demonstrate his talk.

Numerous points in reference to the care and proper use of pyrometers were brought out and much good advice was given on what not to do.

Mr. McCormick's talk was very comprehensive and instructive. At the close of his talk he answered many questions and cleared up many of the misapprehensions of those present.

SOUTH BEND CHAPTER

The January meeting of the South Bend chapter was held on Jan. 10 at the Studebaker corporation plant No. 2. About 40 members and guests were present.

R. E. Lewton, chairman of the research committee the South Bend chapter, delivered a very capable and interesting talk entitled "Some Fatigue Properties of Spring Steel." This talk was illustrated by slides and microphotographs.

Discussion on Mr. Lewton's paper will be held at the February meeting.

The main feature of the evening was Professor E. G. Mahin, Professor of Analytical Chemistry at Purdue university. His subject was "Nonmetallic Inclusions in Steel." This lecture was also illustrated by slides which showed graphically conditions of nonmetallic inclusions. An interesting discussion followed Professor Mahin's lecture.

The South Bend chapter is planning for a large meeting in February. Mr. Thum, associate editor of *Chemical and Metallurgical Engineering* will address the chapter on the subject "Relation of the Metallurgist to the Management."

ST. LOUIS CHAPTER

The regular monthly meeting of the St. Louis Chapter of the American Society for Steel Treating was held Monday evening, January 16th, in the American Annex Hotel. A get-together dinner was served at 7 p. m. to a rather large turn-out of members and guests.

The program for this meeting consisted of a paper by J. E. Burns, metallurgist of Indianapolis, Indiana, who presented a very capable paper entitled "Carburizing Methods and Uses."

Mr. Burns is an authority on the subject of carburizing, having had years of practical shop experience in charge of metallurgical work in automotive plants, combined with field experience which has carried him into hundreds of shops, so that he was able to give the members some of the most up-to-date information on the subjects of carburizing and case hardening.

Mr. Burns' paper proved very instructive and interesting to all those members and guests who had the privilege of hearing him. Following the paper an interesting and lively discussion was held.

SYRACUSE CHAPTER

On Friday evening, January 5th, the Syracuse chapter of the American Society for Steel Treating had the honor of listening to Enrique Touceda, consulting engineer for the American Malleable Castings Association, who presented a very capable paper on malleable iron.

Enrique Touceda is a recognized authority on the subject of malleable iron and presented some very interesting facts upon this subject, pointing out its valuable use in the industries as well as the manner in which it is controlled throughout the manufacturing and producing industries.

Through the efforts of the Malleable Association the quality of malleable cast iron has been constantly increased and controlled until at this time it holds a very enviable position in the automobile and allied indus-

tries, being a very favorable competitor to cast steel, as well as structural and forged steel.

Prior to the regular meeting hour the usual get-together dinner was served at the University Club at 6:30 p. m. An unusually large attendance was had at both the dinner and the meeting following.

TRI CITY CHAPTER

The Tri City chapter of the American Society for Steel Treating held its monthly meeting in the Davenport Chamber of Commerce rooms on Thursday evening, Jan. 18. The meeting was called to order at 8 p. m. by the chairman. The chairman gave the results of the membership and attendance contest as of Jan. 1, 1923 and stated that the Tri City chapter was in fifth place. Increased membership and regular attendance at meetings was urged. A. H. Putman was appointed chairman of the membership committee.

The speaker of the evening was James P. Gill, metallurgist of the Vanadium-Alloys Steel company, Latrobe, Pennsylvania who spoke on "The Tempering of Tool Steels." His talk was illustrated by lantern slides. Mr. Gill first showed the ordinary table of tempering colors and temperatures. He then showed that the tempering color was a function of time as well as temperature. In other words, with the same temperature, the entire range of tempering colors may be secured by varying the time element. Mr. Gill showed characteristic curves, plotting tempering temperature against Brinell hardness. These curves were given for alloy steels as well as for carbon steels. Mr. Gill brought up the question as to whether these steels should be slowly or rapidly cooled after tempering. He quoted from several authorities showing that there is a great deal of conflict on this question. Results of test on nickel steels were stated giving the Izod values for the steels corresponding to the various methods used in cooling from the tempering temperature. There was considerable discussion of the paper.

The meeting was then turned over to Robert B. Kerr, who started a round table discussion on the subject of "Molten Baths for the Heat Treatment of Steel." The advantage and disadvantages of lead and various salts were stated and discussed by various members.

It was announced that the next meeting would be held on Thursday, Feb. 22 at the Davenport Chamber of Commerce. The speaker will be Paul D. Merica who will talk on "Nickel and Nickel Steel." Upon a motion of Mr. Kerr, seconded by Mr. Drew, the meetings for the remainder of the year will be held at the Davenport Chamber of Commerce.

The meeting adjourned at 10:20 p.m.

WASHINGTON CHAPTER

The January meeting of the Washington Chapter was held Friday evening, January 26th, 1923, in the Auditorium of the New Interior Department Building, corner of 18th and F. Sts., N.W.

B. H. DeLong, metallurgist of the Carpenter Steel Company, Reading, Pa., was the speaker for this evening.

He presented a very capable paper entitled "The Manufacture of Alloy Steels." Mr. DeLong described in detail the methods and practices used

by the Carpenter Steel Company in the manufacture of alloy steels by the crucible, electric and open-hearth processes.

Due to the fact that Mr. DeLong has had long experience in the production of all types of alloy steels, including high-speed steels and his intimacy with their application in the industry particularly fitted him to present this paper in a most interesting and capable way.

A most profitable discussion followed Mr. DeLong's paper, and many points of interest and value were brought out.

WORCESTER CHAPTER

The January meeting of the Worcester chapter was held at the plant of Walden Worcester company, 475 Shresbury St., Worcester, Mass. The feature of this meeting was a paper and demonstration by Charles Karl of the Vanadium-Alloys Steel Co., showing the hardening of high-speed tools.

In addition, F. J. Evans of the Surface Combustion company gave an illustrated talk on surface combustion as applied to heat treating furnaces.

This meeting was very well attended and proved to be a very instructive and profitable one to all the members and guests who had the privilege of attending.

Question Box

(Continued from Page 571)

indicates that the elastic compressive strength of ductile steel is somewhat greater than the elastic tensile strength except in the case of soft steel. The amount of working or rolling has a marked effect upon the elastic tensile and compressive strengths of steel. Steel which has been rolled into comparatively thin plates or small shapes has an elastic compressive strength approximately 5 per cent greater than the elastic tensile strength whether the elastic strength is judged from the proportional limit, useful limit point, or yield point. In the case of soft steel having relatively little working in the rolling process, the compressive proportional limit is much greater than the tensile proportional limit, while the yield point in compression is somewhat less than the yield point in tension. It appears, therefore, that the criterion of elastic strength may be of much importance, that the tension test so generally used to judge of the elastic properties of steel is not wholly reliable, and that it may be necessary to resort to auxiliary compression tests for material to be used under certain conditions of combined stress and for critical compression members, at least, until test results and the treatment received by the material can be correlated through more extensive experimental investigations. To what extent the increased compressive strength due to rolling may be attributed to compacting, causing a denser material or attributed to the arrangement of the crystals of the constituent elements in steel or to other factors is not definitely known. The problem offers opportunity for fruitful experimental work.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A repesents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ARTZ, R. R., (A-11), Vanadium Alloys Steel Co., Latrobe, Pa.
ATHY, L. C., (Jr-12), 139 West 11th Avenue, Columbus, Ohio.
BAKER, R. E., (M-1), Rock Island Arsenal, Rock Island, Ill.
BEDWORTH, R. E., (M-1), Westinghouse Research Laboratory, E. Pittsburgh, Pa.
BLAKE, L., (M-1), Standard Motor Parts Company, Lebanon, Ind.
BOND MANUFACTURING CORP., (S-12), Wilmington, Del.
BOYLE, C. L., (A-10), 1298 Baniteau Avenue, Detroit, Michigan.
BROOKFIELD, W. B. Jr., (M-1), 868 Ostrom Avenue, Syracuse, N. Y.
BROWN, H. E., (M-1), 3615 Superior Avenue, Cleveland, Ohio.
BRUCE, Y. J., (Jr.-12), 34 Chittenden Avenue, Columbus, Ohio.
COLKET, T. C., (M-12), 2008 DeLancey Street, Philadelphia, Pa.
COOPER, CLARK, Jr., (M-1), Box 414, Millersburg, Pa.
CUSAC, W. R., (M-9), 1669 Hazelwood Avenue, Detroit, Mich.
DICKMAN, O. D., (M-1), 1085 Cortland Street, St. Paul, Minn.
EVERETT, A. M., (M-12), 29 Warren Avenue, Somerville, Mass.
GALBRAITH, NELSON, (M-1), 717 Rush Street, South Bend, Ind.
GELDER, R. H., (Jr.-12), 176-15th Avenue, Columbus, Ohio.
GRIFFITHS, Wm. E., (Jr.-1), 59-16th Avenue, Columbus, Ohio.
HAMILTON, S. R., (M-1), 2334 E. Grand Blvd., Detroit, Mich.
HAWKINS, R. D., (Jr.-12), 2190 Indianola Avenue, Columbus, Ohio.
HENRY, C. J. W., (M-1), 116 Sanders Avenue, Scotia, N. Y.
KELLY AXE MFG. CO., (Sb-12), Charleston, W. Va.
KELLY, W. C., (S-1), Kelly Axe Mfg. Co., Charleston, W. Va.
KINSEY, C. R., (M-1), 15216 Loomis Ave., Harvey, Ill.
LEETE, A. C., (A-10), Box 38, Hamburg, N. Y.
LENNOX, G. A., (A-10), Driver-Harris Co., Harrison, N. J.
MAHLIE, C. C., (Jr.-12), 1027 Waldeck Street, Columbus, Ohio.
MALIN, J. A., (Jr.-11), 70 E. Clopin Street, Germantown, Pa.
McOMBER, M. F., (M-12), 6340 Douglas Ave., E. Pittsburgh, Pa.
MENGEL, A. C., (M-1), Ballston Lake, N. Y.
OWEN, R., (M-1), 6932 Keystone Street, Philadelphia, Pa.
PERRY, A. S., (M-1), 226 McClellan Street, Schenectady, N. Y.
PETERSON, G., (A-1), 1420 Pennsylvania Blvd., Philadelphia, Pa.
RENIKOFF, L., (M-12), 613 14th Ave. S., Minneapolis, Minn.
SCHAFER, H. W., (M-12), 1005 S. Lafayette St., South Bend, Ind.
SCHNELL, WM., (M-12), 584 Marsten Ave., Detroit, Mich.
SCHUVER, N. L., (A-12), 26 N. Munroe Terrace, Dorchester, Mass.
SOLDERITCH, L. J., (M-10), 2240 Erskine Street, Detroit, Mich.
SYKES, G., (M-10), Gray Tractor Co., Minneapolis, Minn.
TOWNSEND, J. H., (S-12), 1330 Buttonwood Street, Philadelphia, Pa.
VOGEL, H., (M-1), Union Electric Steel Co., Carnegie, Pa.
WENTWORTH, R. W., (A-12), 514 Merchants Bank Bldg., St. Paul, Minn.
WRIGHT, C. R., (Jr.-11), 320 John St., Rockford, Ill.
WRIGHT, E. C., (M-10), University, Alabama.

CHANGES OF ADDRESS

BARKER, T. E., from Denver, Colorado, to 210 Larch Ave., Elmhurst, Ill.
BELKNAP, R. E., from Bethlehem Steel Co., Chicago, to Bethlehem Steel Co., Boston, Mass.
BRILL, M., from Cleveland, Ohio, to 552 N. 2nd St., Philadelphia, Pa.
FLOYD, P. E., from Indianapolis, Ind., to 1238 Washington Blvd., Chicago, Ill.
GERMAN, J. P., from Waterbury, Conn., to Bennett Metal Treating, Elmwood, Conn.
GRAHAM, E. H., from Heppenstall Forge & Knife Co., to 618 Book Bldg., Detroit.
GRAHAM, W. F., from Hartford, Conn., to Curtis Bay Copper & Iron Wks., Baltimore, Md.
HOFFSTETTER, F. B., from R. K. LeBlond Machine Tool Co., to Seiffert & Woodruff Co., Cincinnati, Ohio.
HORNER, W. C., from Montcalm St., to Box 1005, Indianapolis, Ind.
HUGHES, A. F., from E. 62nd St., to 8127 Blackstone Ave., Chicago, Ill.
JAYME, W. A., from Canton, Ohio, to 19 Pomander Walk, New York City.
JOHNSON, F. E., from Lexington Ave., to 132 155th St., Harvey, Ill.
KINGSBURY, J. A., from 503 W. Third St., Mishawaka, Ind., to 314 Angela St., South Bend, Ind.
KOPENHOEFER, C., from Summit Ave., to 820 Mt. Hope, Cincinnati, O.
LOEFFLER, G. O., from Carbon Steel Co., to Bellefield Dwellings, Pittsburgh, Pa.
McFARLAND, J. L., from Box 954 to 11 Columbia St., Schenectady, N. Y.
NEIL, E. B., from Harrold Motor Car Co., to Fisk Bldg., New York City.
NETHAWAY, F. R., from Concord, Detroit, to 607 W. Barnes St., Lansing, Mich.
RIMBACH, R., from W. North St., to 327 McKee Place, Butler, Pa.
SCHAGRIN, H., from Tulsa, Okla., to 1008 E. 42nd Place, Chicago, Ill.
SMITH, E. C., from Book Bldg., Detroit, to Central Steel Co., Massillon, Ohio
SWANDER, C. B., from Wagner Elec. Co., to 5621 Maple Ave., St. Louis, Mo
WALKER, E. C., from N. Blvd., to 175 N. Humphrey Ave., Oak Park, Ill.
WARD, W. J., from Corry, Pa., to Union City, Pa.

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

WANTED—Position as Department Foreman in Heat Treating or Supervisor of Furnace Erection. Have had eight years experience with large firms and am anxious to be located with some firm where efforts to advance will be thoroughly appreciated. Address 12-25.

SUPERINTENDENT or GENERAL FOREMAN of heat treatment department. Experienced in all classes of carbon and high-speed tools and small forgings in quantity in coke, oil, gas or electric furnaces. Shore, Rockwell and Brinell hardness tests. Technical graduate. 15 years experience. Married. Address 12-5

METALLURGIST or CHEMIST. Exceptionally good experience together with a record of absolute satisfaction. Available at once. Eastern location preferred. Address 10-5.

CHEMIST and HEAT TREATER. Technical graduate. Experience in chemical, physical testing and heat treating of steels. Eastern location preferred. Reasonable salary. Address 10-10

POSITION WANTED IN HEAT TREATING LINE. Applicant has had six years experience as foreman in carburizing and can present the best of recommendations. No particular choice as to location, although prefer a position in the vicinity of Cleveland. Address 1-5.

METALLURGIST—desires position. Experienced and technically trained in chemical analysis, physical testing, microscopic work and heat treating of carbon and alloy steels. Address 11-5.

METALLURGIST—1916 Graduate with six years experience as chief chemist and chief metallurgist. Thoroughly familiar with ferrous and non-ferrous analysis, metallurgy, metallography and physical treatment. Has had also good production experience, having had charge at Steel melting and heat-treating departments. During past year has been metallurgist for a Government Arsenal, in charge of ferrous and non-ferrous research and testing. Available at once. Address 1-10.

GRADUATE CHEMIST who has had several years experience in metallurgical analysis, analysis of iron and steel, etc. His work will be for the present, at east, wholly analytical. Address 10-20.

CHEMIST and HEAT TREATER. Technical graduate. Experience in chemical, physical testing and heat treating of steels. Eastern location preferred. Reasonable salary. Address 2-1.

METALLURGIST—Desires Position—Nine years experience both in research and production in tool steel mills, standardization heat treatment of tool steels, metallography ferrous and non-ferrous metals, pyrometry, physical and chemical testing. Address 2-15.

POSITIONS OPEN

TECHNICAL GRADUATE with 2 years (or possibly less) experience. Preferably graduate in mechanical engineering with testing materials experience or training. Man would have variety of work such as mixing alloys, testing of materials and helping with miscellaneous experiments. Approximate salary $150 per month. Location Cleveland. Address 2-25.

TECHNICAL GRADUATE to assist in experimental work in metallographic laboratory preferably with training in physical measurements. Metallurgical training or experience desirable but not absolutely necessary. Approximate salary $150.00 per month. Location Cleveland. Address 2-20.

YOUNG MEN—High grade to travel through the great manufacturing and industrial districts to install, inspect and test electrical instruments and temperature controlling equipment; special consideration will be given to applicants having had experience in handling instruments, meters, gauges, recorders, controllers, etc.; educated men preferred; unusual chance for promotion; write, stating experience, education, age and salary desired. Address 12-20.

FOREMAN to take charge of hardening department in plant in east. Must be able to harden tools, such as broaches and reamers and carbon and high-speed steel as well as case hardening. Address 12-1.

UNUSUAL opportunity to secure exclusive sales agency for tool steel mill in Detroit and Los Angeles districts. Mill long established and products of proven quality. Would require experience in selling steel and moderate capital. Address 9-15.

WANTED A MAN—to take charge of heat treating department in an eastern city. An expert metallurgist is not a requirement for this position but a man who is familiar with carburizing and general heat treatment routine. Address 11-15.

WANTED—Metallurgist with mature experience in the melting and casting of nickel-chromium alloys. Permanent position offered by established concern. Erecting new plant shortly. Address 11-20.

ANALYTICAL CHEMIST thoroughly familiar with the analysis of steel and steel works materials. Write, stating age, experience and salary required. Address 10-15.

FOR SALE

FOR SALE—Two Wilson-Maeulen Tapalog Recorders, 4 point, 75-1800°F. Scale. Condition perfect, practically new. Can be purchased for less than one-half factory price. For further information write Box No. 2-5 A. S. S. T.

Commercial Items of Interest

A BULLETIN, showing exhibition plans and booth specifications, has been sent out by the American Foundrymen's association, 140 S. Dearborn street, Chicago, which will hold its annual exhibit in the public auditorium, Cleveland, April 28-May 3. Contrary to former custom, this year the exhibition will open at 10 a. m. on Saturday, April 28, and will remain open until 10 p. m. It will be closed on Sunday but will be open from 9 a. m. to 5 p. m. on Monday, Tuesday, Wednesday and Thursday, April 30 to May 3. With the opening arranged for Saturday instead of Monday, it is believed less difficulty will be experienced in obtaining shipments from freight offices and getting machinery in position.

Albert H. Miller, chief metallurgist of the Nicetown works of the Midvale Steel & Ordnance Co., died recently at his home at Ambler, Pa. He was 43 years old and a graduate of the University of Pennsylvania. He entered the employ of the Midvale company in 1901 and was a member of the Philadelphia chapter of the American Society for Steel Treating.

The United States civil service commission announces an open competitive examination under the title of Junior Aid, Grade 1, and Junior Aid, Grade 2, on March 21, 1923.

These examinations cover positions included in the usual entrance grades of the scientific and technical staff of the bureau of standards, department of commerce, and preference in appointment will be given to those who state in their applications that they intend to pursue a scientific career.

The position of laboratory apprentice in the Bureau of Standards will be filled from this examination.

For further information regarding these examinations, address the United States Civil Service Commission, Washington, D. C.

The Ingersoll-Rand Co., 11 Broadway, New York, and the A. S. Cameron Steam Pump Works announce the opening of a branch office at 718 Ellicott Square building, Buffalo, equipped to render full service in compressors, pumps, condensers, oil and gas engines, pneumatic tools and drills.

It was with sincere regret that we learned of the death of A. O. Blaich, one of the charter members of the society and a man very well known in the heat treating business.

Mr. Blaich who had been in Europe for about a year, had recently returned and while helping an over-turned auto party near Hammond, Ind., another automobile ran him down, breaking several bones and puncturing a lung. Although having been stricken with pneumonia he was on the way to recovery when a blood clot formed, causing his death.

Mr. Blaich was a very fine gentlemen and it is with much regret that his old friends have learned of his death which occurred the day after Christmas.

The Metal & Thermit Corp., with plants in Chrome, N. J., Chicago and South San Francisco, has announced its intention of erecting a sheet plant at the latter works to cost approximately $2,000,000.

The company recently purchased an additional 14 acres adjoining their present detinning plant in South San Francisco, making a total plant site of 26 acres. Construction of the open-hearth furnaces, of which there will be two at the start, and the mill will be started in the immediate future and it is thought that the plant will be completed and ready for production in the latter part of this year. Plans are being furnished by Pittsburgh engineers and the project will be financed by eastern capital.

The company at present produces about 30,000 tons of melting steel per year through their detinning process. In addition to this scrap supply another 25,000 or 30,000 tons of melting steel will be purchased in the open market, giving the new sheet mill a total capacity of at least 50,000 tons per year.

The Sheldon Axle & Spring Co., Wilkes-Barre, Pa., plans for the immediate rebuilding of the portion of its No. 1 spring mill, destroyed by fire Jan. 4 with loss estimated at $200,000, including equipment. It is expected to suspend production for about a month.

The Hendee Mfg. Co., Springfield, Mass., has purchased the plant and business of the Harley Co., of the same city, manufacturer of castings and drop forgings, at a foreclosure sale, for $625,000.

The Keller Mechanical Engineering corporation was recently chartered to take over the business of the Keller Mechanical Engraving Co., 70 Washington street, Brooklyn, N. Y., increasing its capital from $425,000 to $550,000, all but $50,000 of which has been issued. Orders on hand have so increased and present floor area is so crowded that additional space has been obtained in the Sweeney building on the opposite side of the street. Some months ago the management considered the construction of a plant, but plans were put aside in an effort to keep abreast the demand. Eventually it will most likely become imperative to reconsider building. Two new machines, a flexible shaft grinder and a stamp making machine, have been added to the company's line, besides the Type F die sinking machine exhibited in Detroit last October, at the International Steel exposition.

In the reorganization Sidney A. Keller, formerly president, becomes treasurer and general business manager, Joseph F. Keller is president in charge of works and developments; Jules Dierckx, vice president and sales manager; L. A. Tranzer of the firm, Tranzer & Lane, New York, secretary; and E. A. Anderson, assistant secretary.

The new electrically driven mills of the Driver-Harris Co. at Harrison, N. J., have been put in operation during the past year. This company rolls monel metal, nichrome and other non-ferrous materials. This installation consists of a 500 horsepower and an 800 horsepower motor, with automatic starting equipment for the motor generator set which supplies these motors. The automatic starting feature makes it unnecessary to employ an attendant to look after the motor generator set.

W. J. Griffith has been appointed superintendent of Nos. 1 and 3 open-hearth departments of the Bethlehem Steel Co., Bethlehem, Pa., succeeding S. S. Ball, resigned. Other changes include the retirement of William J. Shennan, as superintendent of the iron, steel, pattern shop and brass foundries, following 42 years service with the company. He will be succeeded by Captain J. M. Lund. W. F. Lantz has been appointed chief chemist succeeding A. D. Shankland who has been made metallurgical inspector at No. 1 and No. 2 mills.

The Penn Seaboard Fuel corporation, 1714 Sansom street, Philadelphia, is considering the installation of a steam hammer, with pressure of about 150 pounds per square inch.

Temperature

With the **F. and F. Optical Pyrometer** the temperature is measured by merely observing the object. It is accurate, simple, substantial and direct-reading.

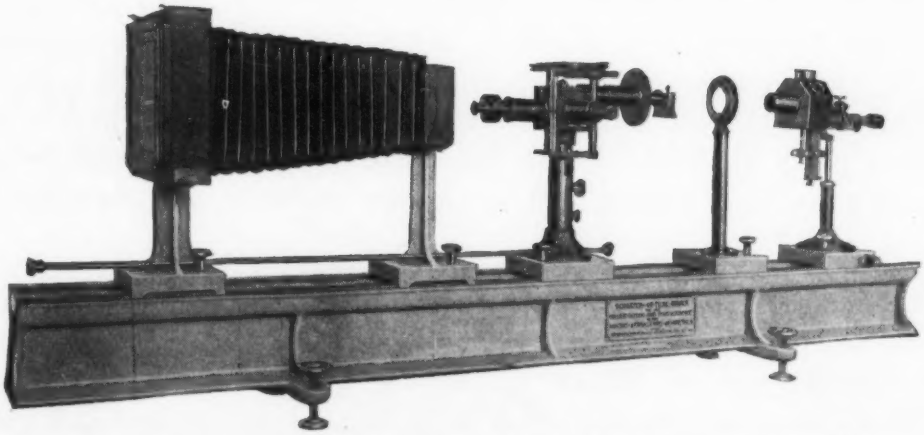
(Write for Booklet)

Hardness

The **S. M. Co. Brinell Machine** is the standard machine for measuring hardness of metals adopted by the leading concerns.

Pressure is applied quickly and uniformly; a special feature prevents leakage of the hydraulic fluid.

Micro-Structure



The **Scimatco Optical Bench** is the advanced outfit used by many of the foremost metallurgical firms for observing and photographing the micro structure of metals.

SCIENTIFIC MATERIALS COMPANY

"Everything for the Laboratory"

PITTSBURGH, PA.

The Simonds Mfg. Co., and the Simonds File Co., both of Fitchburgh, Mass., have combined under the name of the Simonds Saw & Steel Co. with $1,000,000 capitalization in bonds and $55,000 in common stock, no par value. The Simonds Mfg. Co. was organized in 1868, and in 1905 purchased control of the Fitchburg File Co., which then became the Simonds File Co. with capital of $100,000. The Simonds Saw & Steel Co. has two plants at Fitchburg and 800 operatives, a Chicago plant employing 350 and a Lockport, N. Y., plant employing 450, as well as a Montreal subsidiary employing 150. The new combination will have no bearing on the personnel of plants. Alvan T. Simonds is president; Harlan K. Simonds, treasurer; J. E. Kelley, secretary; and Thomas F. Howarth, H. A. Sargent and O. A. Olsen, vice presidents.

The Weldless Rolled Ring Co., Cleveland, has been organized and will establish a plant at 10022 Detroit avenue for the manufacture of ring gear blanks and bearing ring blanks used in the automotive industry. Rings will also be made for the textile industry. Equipment is now being installed and it is expected that the plant will be in operation about Feb. 1. The company was formed by former executives of the Washington Steel & Ordnance Co., Washington, D. C. Samuel V. Hunnings, former metallurgical superintendent of the Washington company, is president, Charles R. Marsh of New York secretary-treasurer, and C. C. Venable chief engineer. These officers, with C. R. Cross and A. L. Alexander, constitute the board of directors.

Dodge Brothers, Inc., Detroit, Mich., has plans in preparation for two additions, comprising a four-story and basement building, 100 x 450 feet, and one-story structure, 85 x 100 feet. The first noted will be used as a parts department, and the other for general operating service. Smith, Hinchman & Grylls, 800 Marquette building, are architects.

The United States Civil Service Commission announces an open competitive examination for junior engineer, junior physicist and junior technologist on March 7, 1923 at any of the places listed on the bulletin at which examination is requested in applications received in time for the mailing of examination papers.

The vacancies in the Bureau of Standards, Department of Commerce for duty in Washington, or elsewhere at $1200 and $1500 a year, plus bonus and in positions requiring similar qualifications will be filled from these examinations.

Further information in reference to these examinations may be obtained by addressing the United States Civil Service Commission, Washton.

SIMONDS
STEEL
CRUCIBLE ═══ ELECTRIC

High Speed Steel
Magnet Steels
Chrome Ball and Bearing Steels
Carbon and Alloy Tool Steels
Special Steels

TO know that the steel ordered today will duplicate in every respect that which gave unusual efficiency six months ago, is a satisfaction to the consumer made possible only by years of experience in making QUALITY Steels UNIFORM at all times.

SIMONDS STEEL in your hardening room allows you fixed temperatures in heat treating and eliminates those costly "trouble days".

We Develop Steels Required
For Particular Hard Usage

Bars Sheets Billets

SIMONDS SAW AND STEEL CO.
STEEL MILLS
LOCKPORT, N. Y.

Edgar T. Ward Sons Co., Distributors

E. B. Neil is now connected with the American La France Fire Engine company, Fisk building, Broadway & 67th street, New York City. Mr. Neil is in charge of the catalog editorial department relating to the company's new line of commercial trucks which are at this time being placed on the market.

The Bethlehem Steel Co., Bethlehem, Pa., will remodel a three-story building, 60 x 320 feet, heretofore used as a machine shop, for other branches of structural steel and miscellaneous engineering operations. The work will cost about $300,000.

George H. Grundy has resigned as general sales manager of the Poldi Steel Corp. of America, New York company. He has been succeeded temporarily by Reginald Wilson.

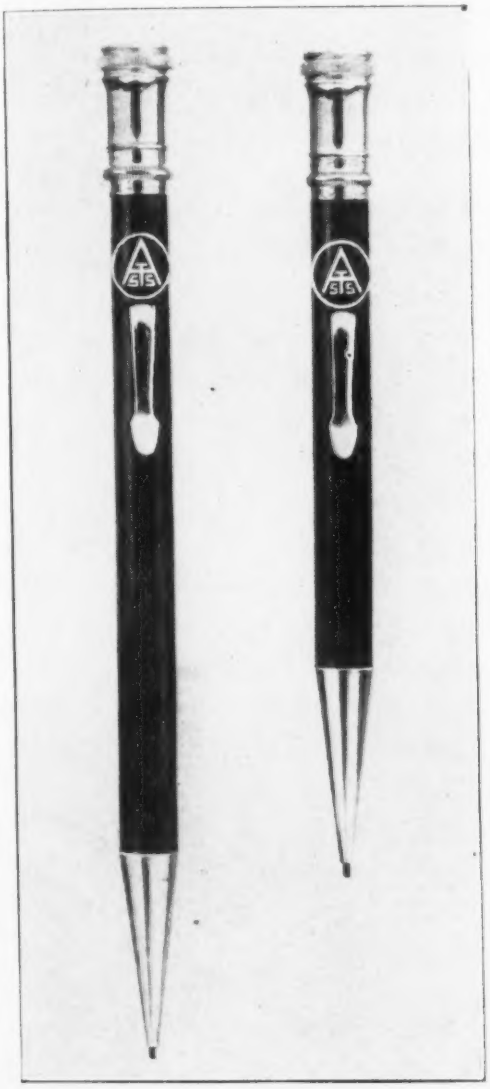
The Bethlehem Shipbuilding Corp. Ltd., announces the appointment of H. G. Smith as vice president in charge of sales, offices at 25 Broadway, New York City.

The Timken Roller Bearing Service & Sales Co., with branches in all of the principal cities in the United States, has been formulated and will take care of the service and distribution work of the Timken Roller Bearing Co. The new company will be under the direct supervision of the older company.

After the first of February, 1923, E. S. Newcomb, representative of the Charles Engelhard, Inc., of New York, manufacturers of pyrometers and heat measuring instruments, will occupy his new offices and quarters in the Newman-Stern building, 1740 East Twelfth street, Cleveland, O.

W. F. Graham, formerly of the Henry Souther Engineering Co., of Hartford, Conn., has recently been appointed metallurgist of the Curtis Bay Copper and Iron Works, Curtis Bay, Baltimore, Md.

John P. German for eight years with the Scovill Mfg. Co., at Waterbury, Conn., in charge of the hardening department, has taken a position with the Bennett Metal Treating Co., of Elmwood, Conn. Mr. German has been a member of the American Society for Steel Treating for several years and is one of the best all around tool hardeners that the steel business can boast of.



The NU-TYPE is the most beautiful and artistic pocket pencil on the market. In construction, in artistic finish and design, in its sturdy wearing qualities it endears itself to its users. It is a "different" pencil, and a better pencil.

The barrel is made of light, hard, enduring rubber composition which takes a very handsome finish. These pencils are to be had in either round or octagon shape. The rubber barrel is, in turn, reinforced with a metal tube which, by its special design, insures a splendid combination of strength and lightness.

A common defect in other pencils of this type is the ease with which the leads break in feeding through the tip. This defect is remedied by a specially constructed tip and by the dual gripping action on the lead.

NU-TYPE is known as "The Panel Pencil." The panels, clips, nuts, as well as the tips and caps, are made of 14k gold filled or sterling silver. These panels are attached to the pencil, just above the clip, a patented feature, and are engraved with the A. S. S. T. emblem.

PRICES, POST PAID

No. 140—Round Barrel, 5¼", Panel lock and A.S.S.T. clip, 14k Gold Filled $2.75

No. 150—Octagon Barrel, 5¼", Panel lock and A.S.S.T. clip, 14k Gold Filled 3.25

No. 70—Round Barrel, 4¼", Panel lock and A.S.S.T. clip, 14k Gold Filled 2.75

No. 80—Octagon Barrel, 4¼", Panel lock and A.S.S.T. clip, 14k Gold Filled 3.25

In Sterling Silver, 50c less. Order by number. Send orders to

American Society for Steel Treating

4600 Prospect Ave. **Cleveland, O.**

The Case Hardening Service Co., 2281 Scranton road, Cleveland, is sending out a leaflet on Bohnite, calling attention to its merits.

Ray G. White, formerly Chicago branch manager of B. M. Jones & Co., Inc., has been appointed Eastern railroad sales agent for the McInnes Steel Co., Ltd., Corry, Pa., manufacturer of hammered crucible tool steels. He has opened a temporary office at 56 Murray street, New York.

Professor Samuel S. Keller, head of the departmentment of mathematics at Carnegie Institute of Technology, Pittsburgh, died in Johns Hopkins Hospital, Baltimore, on January 12, from complication of diseases. He was born in Springfield, O., on November 1, 1867, was a graduate of Wittenburg college, and had taught at Yale and at Wittenburg prior to his seventeen years of service as a member of the faculty at Carnegie Tech.

The Spencer Turbine Co., manufacturer of turbines, etc., Hartford, Conn., has recently increased its authorized capital stock from $300,000 to $600,000.

According to an announcement in Pittsburgh, the Oliver Iron & Steel Co. and the Morris & Bailey Steel Co. have been merged. The new company, which will have a capital of $8,000,000 will be known as the Oliver Iron & Steel Corp., with Henry Oliver as president. The management of the two companies in the merger will continue as in the past.

The Oliver Iron & Steel Co. was founded shortly after the Civil war by the late Henry W. Oliver and his brothers, David B. and James B. Oliver. The Morris & Bailey Steel Co. was founded by William J. Morris.

The W. A. Jones Foundry & Machine Co., 4401 West Roosevelt avenue, Chicago, announces that an entirely new edition of their Jones Spur Gear Speed Reducer Catalog No. 26 is now ready for distribution.

The information contained therein is of exceptional value to consulting engineers, superintendents, chief engineers, master mechanics, in fact to anyone who specifies mechanical drives for factories, mills, mines or plants.

It is the company's desire to place copies of this edition in the hands of all those who are vitally interested in speed reduction problems.

In preparing this new and most complete treatise on speed reduction drives, the company endeavored to make it the standard work of its kind. It embodies technical and practical information, complete descriptive matter and illustrations of typical drives.

The installation section presents pictorially reducer drives in many large industrial plants.

Dimensions, weights and horsepower ratings for complete speed reduction sets are shown.